VICTORIA.

GEOLOGY AND PHYSICAL GEOGRAPHY,

BY

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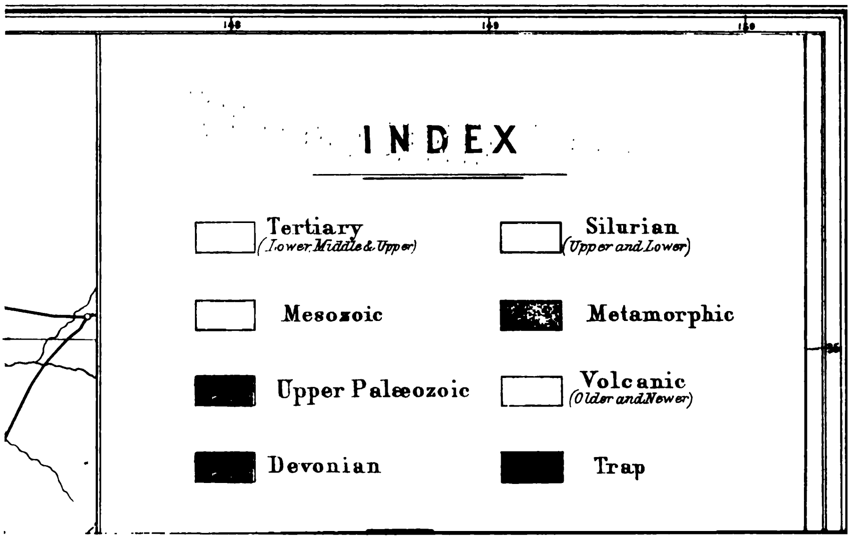


regular progress, under the direction of Mr. A. R. C. Selwyn, assisted by the late Messrs. C. D'Oyley Aplin and R. Daintree,

PREFACE.

THE want of a Manual of Victorian Geology has been frequently expressed; and though able writers have dealt with the subject, some of their works have not been so prominently placed before the public as their merits entitled them to be, while others are out of print, and copies remain in the hands only of a few.

An essay on mining in the colony of Victoria was prepared and published by Mr. A. R. C. Selwyn, then Government Geologist, in connexion with the catalogue of the Victorian Exhibition in 1861.

In connexion with the Intercolonial Exhibition of 1866, a pamphlet was published, entitled "Mining and Mineral Statistics," by Mr. R. Brough Smyth, then Secretary for Mines.

An excellent work on the physical geography, geology, and mineralogy of Victoria, by Mr. A. R. C. Selwyn and Mr. (now Professor) George F. Ulrich, was also issued in 1866.

In 1869, a large volume, entitled "The Gold-fields and Mineral Districts of Victoria," was compiled by Mr. R. Brough Smyth, who subsequently published a pamphlet styled "Mining and Mineral Statistics, with Notes on the Rock-Formations of Victoria," in connexion with a Geological Sketch-map of the colony, prepared for the Victorian Exhibition of 1872 and the International Exhibition of 1873.

A descriptive catalogue of the rock and mineral specimens in the Industrial and Technological Museum, Melbourne, was prepared, under the direction of Mr. J. Cosmo Newbery, Superintendent, by Mr. George F. Ulrich in 1875, and embodied observations on the leading geological characteristics of Victoria.

From 1856 to 1868, the Geological Survey of Victoria was in regular progress, under the direction of Mr. A. R. C. Selwyn, assisted by the late Messrs. C. D'Oyley Aplin and R. Daintree,

and by Messrs. George F. Ulrich, Norman Taylor, H. Y. L. Brown, Robert Etheredge, jun., Charles S. Wilkinson, and the writer.

At the close of 1868, the Geological Survey Department was abolished by the Government, but in 1871 Mr. R. Brough Smyth, then Secretary for Mines, obtained authority for the partial resumption of the work, which was continued—first under his direction, and subsequently under that of Mr. T. Couchman, his successor—by three geological surveyors, Mr. Norman Taylor, Mr. Ferdinand M. Krausé, and myself, until the beginning of 1878, when all three were dispensed with.

As the only field geologist subsequently reinstated, and now in the service of the Victorian Government, upon me devolves the duty of preparing an essay showing the progress made up to date in acquiring a knowledge of the geology of the colony. The work is a digest of the principal information noted in the publications above mentioned, in the subsequently-issued geological progress reports of the Mining Department, and in the works of Professor McCoy, Mr. A. W. Howitt, and others.

The small amount contributed from original personal observation gives me no claim to appear otherwise than as a compiler, and I undertake the task fully conscious that a life passed from boyhood principally in the forests and ranges within the narrow limits of Victoria has not been favorable to the acquirement of a scientific education sufficiently advanced to enable me to furnish an essay that will bear comparison with those of more gifted authors, who have enjoyed the advantages of regular scientific tuition and more extended field experience. If, however, there is no geological fact mentioned in this work that has not been already noticed by others, there are few that have not been verified by personal observation.

The leading characteristics of Victorian geology were ascertained by Mr. A. R. C. Selwyn, and a large area was geologically surveyed in detail under his supervision. As regards general outlines, little can be added to the information collected by him, though in matters of detail some corrections and amendments have

been made both with respect to the Geological Sketch-maps, and the conclusions arrived at as to the position of some rock-formations which he had not the opportunity to fully investigate. Irrespective of these matters of detail, to Mr. Selwyn and his principal colleagues is due the credit of having first demonstrated the leading facts of Victorian geology, and of having arrived at general conclusions, which the results of subsequent inquiry have in most cases tended to substantiate.

The latest Geological Sketch-map of Victoria, prepared under the direction of Major Couchman, late Secretary for Mines, is—with the addition of being geologically coloured—the topographical map issued from the Crown Lands Department, under the supervision of Mr. A. J. Skene, late Surveyor-General.

A few modifications and improvements, as regards detail on previous sketch-maps, have been effected, but owing to the practical cessation since 1877 of geological survey on an organized basis, and the limited time at my disposal for the work of revision in the field, the improvement is not so marked as it might have been. The map will, however, be found to contain valuable scientific information, and, if studied in connexion with the various detailed maps, drawings, and writings extant on Victorian geology, cannot fail to prove of interest to scientific men and students of geology.

Mr. A. J. Skene's map of Australia and Tasmania, geologically coloured by Mr. A. Everett, chief draughtsman of the Mining Department, has been prepared under the direction of the Secretary for Mines from the most authentic data obtainable.

It will be found to be a most useful adjunct to the study of the Victorian map, and will illustrate the remarks as to the physical geography and geology of this colony as related to the rest of Australia which will be met with in this essay.

Sixty-five geological quarter-sheets, each representing, on a scale of 2 inches to 1 mile, an area of 54 square miles, were prepared from minutely-detailed surveys under the directions of Mr. A. R. C. Selwyn.

Similarly prepared maps of the principal gold-fields, namely, Stawell, Ararat, Clunes and Talbot, Ballarat, Creswick, and

Sandhurst, with sketch-maps of a considerable area in Gippsland, have been published under the directions of Mr. R. Brough Smyth and Major Couchman, late Secretaries for Mines, and of Mr. Charles W. Langtree, who now holds that office.

Seven Progress Reports have also been issued, embodying the individual reports of the geological surveyors, with papers by other contributors, and illustrative plans, sections, and drawings. Eight decades, illustrating the palæontology of Victoria, have been prepared and published under the direction of Professor McCoy; and nineteen plates, with accompanying descriptions, of the fossil-fruits found in the Tertiary gold-drifts, have been issued by Baron F. von Mueller, Government Botanist.

CHAPTER I.

PHYSICAL GEOGRAPHY.

The Cordillera and its Spurs. Boundaries of Victoria. Mountain Systems. River Systems. Drainage Areas.

A Cordillera, or mountain chain, conforming approximately in direction to the eastern and south-eastern coast lines of Australia, extends from Cape York, the extreme northern point of the island-continent, through Queensland and New South Wales into Victoria, which latter territory may be described as comprising the south-eastern portion of Australia, and including—under existing orographical conditions—the southern terminal spurs of the Cordillera.

The boundaries of Victoria are—on the west, the 141st meridian; on the south and south-west, the sea-coast from the 141st meridian to Cape Howe; on the north-east, a line from Cape Howe to Forest Hill, a lofty point of the Cordillera which there passes into Victoria; and on the north, the Murray River, from its source near Forest Hill to the 141st meridian. The total area of the colony is computed at 87,884 square miles, the extreme length east and west being about 420 miles, and the greatest breadth north and south 250 miles.

From Forest Hill the Cordillera trends south-westerly to a point near St. Clair, between the head waters of three of the principal rivers of Victoria, namely, the Yarra, falling into Port Phillip; the Goulburn, joining the Murray; and the Thomson, running into the La Trobe River, a few miles above where the latter enters the Gippsland Lakes. From St. Clair, a great spur of the Cordillera extends through the colony, in a general direction slightly north of west to the Glenelg River, near the South Australian border, where the range slopes down to the low-lying and nearly level country, of which the western margin of Victoria from the sea to the Murray principally consists. The Grampians, which include the Sierra, the Victoria, the Dundas, and the Black Ranges, constitute the terminal western points of this mountain chain.

Another spur, which will for the sake of distinction be here termed the Southern Spur, branches from the Cordillera at St. Clair, and extends southerly, but in a very zig-zag manner, to Wilson's Promontory, the extreme southern point of Australia. This spur is not so conspicuous a mountain chain as the western range, but is of geographical importance, being really a portion of the water-shed line extending from the extreme northern to the extreme southern point of Australia.

The question as to which of these two spurs represents the extension of the Cordillera will be discussed after the rock-formations have been described, and data thereby given for the opinion advanced.

The portion of the Cordillera from Forest Hill to St. Clair, and the great range extending westward from St. Clair to the Grampians, together constitute geographically, and will be here referred to as, the "Main Divide" of Victoria, forming the water-shed line between the Murray River system on the north, and the numerous streams debouching on the southern coast between the Snowy River and the Glenelg.

The loftiest summit of the Australian Cordillera is Mount Kosciusko, 7,300 feet above sea-level, situated in New South Wales, about 24 miles northward from Forest Hill. In Victoria, the highest points of the Main Divide are between Forest Hill and St. Clair, the names and heights of the principal ones being as follows:—Forest Hill, (about) 5,000 feet; Mount Cobberas, 6,025 feet; Mount Tambo, 4,700 feet; Mount Hotham, 6,100 feet; The Twins, 5,575 feet; Mount Howitt, 5,715 feet; Connor's Plain, 5,500 feet; Fullarton's Spring-hill, 5,400 feet; and Mount Matlock, 4,561 feet.

Mount Bogong, 6,508 feet, and Mount Feathertop, 6,303 feet, the highest mountains in Victoria, are peaks on northern spurs from the Main Divide, the former between the Kiewa and the Mitta Mitta, the latter between the Kiewa and the Ovens Rivers.

Westward from St. Clair to Mount Strickland, the Divide maintains an average elevation of not less than 4,000 feet; but from Mount Strickland to the Grampians none of the highest peaks attain that altitude.

Mount Disappointment, 2,631 feet; Mount Macedon, 3,324 feet; Mount Buangor, 3,247 feet; Lar-ne-Gerin, 3,123 feet; Mount Ararat, 2,020 feet; and Mount William, in the Grampians, 3,827 feet, above sea-level, are the highest elevations westward from the meridian of Melbourne. The average height of the Main Divide may be approximately stated at about 3,000 feet, some of the lowest saddles being as low as 1,000 feet above sea-level. The Main Divide has a general bearing of a few degrees south of west, taking a direct line from Forest Hill on the north-eastern boundary line to Mount William, the highest peak of the Grampians, in the western portion of the colony. The average distance of the Main Divide from the ocean coast is approximately 70 miles, or about the distance which the two mountains above referred to (Forest Hill and Mount William) are from the mouths of the Snowy and Hopkins Rivers respectively, so that a line between the two latter points is nearly parallel with one between the two mountains.

In its principal deviations, the course of the Main Divide conforms noticeably to the configuration of the coast line; the southernmost point of the former is where the Cordillera bifurcates at St. Clair, and is directly north of Wilson's Promontory, the southernmost point on the coast line. The Divide recedes northward conformably to the indentation of Port Phillip, turns again slightly south-westward, and then deflects north-westward, coinciding in general direction with the coast line from Cape Otway to Portland. Of the spurs branching from the Main Divide on the north only those eastward from the Ovens River extend as far north as the Murray; the spurs westward from the Ovens terminate on level country many miles back from the Murray.

That portion of the Murray River drainage-area which is contained within Victoria lies to the north of the Main Divide, and comprises more than half of the entire area of the colony.

The principal Victorian tributaries of the Murray are the Mitta Mitta, the Kiewa, the Ovens, the Broken River, the Goulburn, the Campaspe, and the Loddon, all of which rise in the Main Divide, and are fed by numerous tributaries. Westward from the Loddon are the Avoca, the Wimmera, and several smaller rivers and creeks which run only during wet seasons, and whose waters rarely reach the Murray, being received and retained in lakes and swamps, the overflow from which is absorbed by the porous soil of the low-lying tract extending from the Avoca to the western boundary of the colony.

On the southern slopes of the Main Divide, the leading spurs separating the principal drainage-areas lying between Cape Howe and Port Phillip, extend down to, or to within a short distance of, the sea; but, to the westward of Port Phillip, a wide extent of low-lying and level or slightly-undulating country intervenes between the foot-hills of the Main Divide and the coast line. An isolated mountainous tract, known as the Cape Otway Ranges, totally unconnected by any conspicuous leading range with the Main Divide, lies to the south of a line from Geelong to Warrnambool. The highest point in these ranges is Mount Sabine, 1,800 feet above the sea, and from the Mount Sabine Range numerous spurs descend to the coast, where they terminate in cliffs and bold headlands.

The Southern Spur, after leaving the Cordillera at St. Clair, trends southward for some miles to Mount Baw Baw, where it attains an elevation of about 5,000 feet; it then turns westerly as far as the head of the La Trobe River, whence it makes a south-easterly deflection, and descends to a level not 500 feet above the sea in the neighbourhood of Drouin, where it forms a low watershed between the valleys of Gippsland and Western Port. From here the Southern Spur rises again, and forms the Strzlecki Range, over 2,000 feet above the sea.

As the Strzlecki Range, and further south-east as the Hoddle Range, it forms the main water-shed of the South Gippsland and Western Port Ranges, and with its numerous offshoots constitutes, within an area lying to the south of a direct line from Western Port to the Gippsland Lakes, a mountainous tract whose only connexion with the Main Divide is the low ridge near Drouin, above referred to.

From the Hoddle Range one spur descends to the sea at Cape Liptrap, while another slopes down to a low narrow isthmus lying between Corner Inlet on the east and Shallow Inlet on the west. South from this isthmus rises a rugged mountainous tract, consisting wholly of granite, of which the highest peak, Mount La Trobe, is 2,400 feet above the sea, and the terminal point is Wilson's Promontory, the southernmost extremity of Australia.

The Southern Spur separates the country lying to the south of the Main Divide into two great divisions, each of which contains a number of distinct drainage-areas. In the eastern division, which comprises nearly the whole of Gippsland, there are several independent streams, draining considerable areas between Cape Howe and the Snowy River. The Snowy River has its sources in New South Wales, but a large extent of its drainage-area lies in Gippsland; its western water-shed line is a range starting from near Mount Tambo, on the Main Divide, and extending to the low country west of the river mouth.

Between the Snowy River and the outlet of the Gippsland Lakes is a small drainage-area, the waters of which pass to the sea through Lake Tyers. From that portion of the Main Divide, extending between Mount Tambo and St. Clair, and from the Southern Spur between St. Clair and the Hoddle Range, rise a number of rivers which irrigate the richest portions of Gippsland, and finally mingle their waters in the Gippsland Lakes, whence they reach the sea by a common outlet. The principal of these rivers are the La Trobe or Glengarry—the Morwell, Narracan, and Moe joining the La Trobe from the south and west; the Tanjil, the Tyers, the Thomson, and the Macalister, affluents of the La Trobe, from the north; the Avon, the Mitchell or Wonnongatta, the Nicholson, and the Tambo. Between the Gippsland Lakes and Wilson's Promontory a number of minor streams empty themselves on the coast or into the various inlets. The Albert and the Tarra running into Port Albert, and the Agnes running into Corner Inlet, head from a range which forms the divide between their waters and those of the Morwell, and is an eastern offshoot from the Hoddle Range. The Franklin, the Bennison, and Stockyard Creek head from the Hoddle Range, and flow into Corner Inlet.

In the main western division, that lying to the south of the Main Divide and to the west of the Southern Spur, are a number of distinct drainage-areas. Anderson's Inlet, between Cape Liptrap

and Cape Patterson, receives the River Tarwin, of which the eastern branches head from the Hoddle Range, and the northern from the Strzlecki Range, both portions of the Southern Spur.

The Powlett River, entering the sea between Cape Patterson and Western Port, heads from a western offshoot of the Strzlecki Range, which extends down to Griffiths Point, and forms the southern water-shed line of the streams falling into Western Port Bay. In the drainage-area of Western Port Bay, the principal streams are the Bass and the Lang Lang, rising in the Strzlecki Range, and the Tarago, formerly Tarween, with its affluent the Buncep, heading from a range which branches south-westerly from the Southern Spur, and forms the divide between Western Port and Port Phillip. For several miles the Tarago skirts the western slope of the Southern Spur at Neerim, and on leaving it receives Brandy Creek, heading from the low "saddle" of the Southern Spur near Drouin. From another portion of this "saddle" small streams flow westward into the Lang Lang. All waters eastward of the "saddle" flow into the Moe, and belong to the Gippsland drainage system.

The Port Phillip Bay drainage-area is a very extensive one. Its principal river is the Yarra, whose extreme sources are near the bifurcation of the Cordillera at St. Clair. The main northern tributaries of the Yarra—the Saltwater or Maribyrnong River, the Plenty, and the Watts—rise in the Main Divide; while of the southern affluents some head from the Southern Spur, and others from the branch range therefrom which divides the waters of Western Port from those of Port Phillip. From this range, portion of which is known as the Dandenong Range, several minor creeks descend to the eastern shore of Port Phillip. The Werribee rises in the Main Divide, and enters Port Phillip midway between Melbourne and Geelong. The Barwon River enters the sea through Lake Connewarre, a little to the west of Port Phillip Heads, and takes its rise at Mount Sabine, the culminating point of the Otway Ranges. The Leigh or Yarrowee and the Moorabool, both northern affluents of the Barwon, have their sources in the Main Divide.

In the Cape Otway Ranges, a number of creeks and rivers head from the Mount Sabine Range. The principal of these are—the Barrum, running into the sea immediately west of Apollo Bay; the Aire, 5 miles north-west from Cape Otway; and the Gellibrand, which heads from Mount Sabine, and, draining the northern portion of the ranges, joins the sea a few miles north-west from Moonlight Head.

Curdie's River intersects the low-lying western portion of the Cape Otway district, and its mouth is about midway between the Gellibrand and Warrnambool. The Hopkins, which drains a wide area, has its outlet at Warrnambool, and its sources in a

considerable length of the Main Divide, extending from north of Ballarat to the Grampians. The Glenelg River, rising in and skirting the northern slopes, flows round the western extremity of the Grampians, and after being joined by the Wannon, which receives their southern drainage, enters the sea at the 141st meridian, or western boundary line of the colony. Several unimportant streams empty themselves at various points along the coast, between the mouths of the Glenelg and the Hopkins.

North of the Cape Otway Ranges, and between the water-sheds of Curdie's River, the Gellibrand, the Hopkins, and the Leigh Rivers, is a district containing numerous lakes, salt and fresh.

The largest of these, and also the most extensive in Victoria, is Lake Korangamite, a salt lake situated in a large central depression, about 350 feet above sea-level. Lake Korangamite receives the drainage of nearly 1,200 square miles, but has no outlet save by evaporation. It has been remarked of the lakes in this district that those with no outlets are salt, while those having outlets are fresh. The explanation is that in the former the salt brought by rain-waters from the soil of the surrounding country has no means of escape, while in the latter it is carried away in solution, and thus does not collect in sufficient quantity to affect the taste of the water Many of these lakes are the craters of now extinct volcanoes.

Briefly recapitulating, we have, as the leading mountain features of Victoria:—1st. The Main Divide, and its branch systems of ranges. 2nd. The South Gippsland and Western Port Ranges, of which portion of the Southern Spur constitutes the leading ridge, and which are only slightly connected with the Main Divide by means of the low "saddle" to which the Southern Spur descends, near Drouin. 3rd. The Cape Otway Ranges, totally unconnected by any leading ridge with the Main Divide, and occupying a great southern projection of the land westward of the meridian of Port Phillip, as the South Gippsland and Western Port Ranges occupy a similar projection eastward thereof. As the principal groups of drainage systems we have—1st, that of the Murray, north of the Main Divide; 2nd, the South-eastern or Gippsland systems, south of the Main Divide, and east of the Southern Spur; 3rd, the South-western systems, or those south of the Main Divide and west of the Southern Spur.

The foregoing description of the principal mountain and river systems has been given somewhat minutely, as I wish hereafter to show how the present physical structure of Victoria is due to a complication of causes, in the form of geological changes, which have been incessantly at work since the remotest epochs. An attempt will also be made to indicate the comparative relations of the sea and land surfaces, and the positions and courses of the principal drainage channels, during various eras in the geological history of this country.

CHAPTER II.

List of Geological Formations. Relations of Main Geological and Geographical Features.

The table of colours and explanations on the Geological Sketch-map of Victoria (8 miles to 1 inch) shows four principal groups, comprising in all thirteen distinct formations, known to exist in the colony, and proved in most cases by palæontological evidence to be the equivalents, as regards geological position, of well-explored analogous formations in Europe and other parts of the world.

On the detailed geological maps are shown several subdivisions —into Alluvial, Post-Pliocene, Newer Pliocene, and Older Pliocene—of the deposits indicated on the sketch-map by one colour, under the general heading of Post-Tertiary and Upper Tertiary. The results of further investigation will, no doubt, justify subdivisions of the Mesozoic and Palæozoic groups.

Subjoined is a table of the principal groups and divisions of Victorian geology, as shown on the Geological Sketch-map above referred to, and the names of the colours used to distinguish them :—

TABLE OF COLOURS AND EXPLANATIONS.

Tertiary or Cainozoic.

(a) 1. *Post Tertiary.*

Colours used on Map.

1. Recent creek and river deposits, forming alluvial flats; sand-dunes; recent sands, clays, gravels, and estuary beds, forming surface deposits of plains bordering the Murray River, from the Ovens to the western boundary of the colony. Sale Plains; Alberton; Plains between Werribee and Little River.

(a) 2. *Upper Tertiary* (*Pliocene*).

(a) Terre Vert.

2. Ferruginous sandstones, with marine shells, Geelong, Flemington, and Brighton; Quartz gravels of the Flagstaff Hill, Melbourne, Haunted Hill, Tom's Cap, and Longford to Woodside in Gippsland, northwards from Stawell towards the Wimmera River; Fresh-water limestones, Geelong; Leaf beds of Daylesford and Malmsbury, Ballarat, Creswick, and Haddon Leads.

Fossils.—Fauna—Mammalia: *Phascolomys pliocenus* (McCoy), *Thylacoleo carnifex* (Owen), *Diprotodon longiceps* (McCoy), *Arctocephalus Williamsi* (McCoy), *Canis dingo, Sarcophilus ursinus, Procoptodon Goliath, Macropus Atlas* (Owen). Fishes: *Charcharodon angustidens* (Ag.), *C. megalodon* (Ag.). Mollusca: *Cerithium Flemingtonensis* (McCoy), *Haliotis nævosoides* (McCoy), *Waldheimia macropora* (McCoy), &c. Radiata: *Lovenia Forbesi* (McCoy), *Monostychia Australis* (Laube), &c. Flora: *Eucalyptus Pluti, Spondylostrobus Smythii, Phymatocaryon Mackayi, Celyphina McCoyi, Conchotheca turgida, Platycoila Sullivani* and others, chiefly by F. v. Mueller.

(b) *Middle Tertiary* (*Miocene*).

COLOURS USED ON MAP.

(b) Yellow Ochre.

White clays, with impressions of leaves beneath the older volcanic, Flemington, Berwick; Ferruginous beds, with fossil flora, Pentland Hills, Dargo and Bogong High Plains; Auriferous gravels, Dargo High Plains, Tanjil, and Russell's Creek; Fossiliferous sands and clays of the River Glenelg; Fossiliferous, sandy, and calcareous beds on the coast between Warrnambool and Cape Otway, and between Loutit Bay and Geelong, Moorabool River, Leigh River, Bairnsdale, Gippsland Lakes' entrance, Longford and Merriman's Creek, near Sale, Curdie's River, and other localities; Lignites, McKirley's Creek, north of Crossover and Tarwin River, near McDonald's Track; Calcareous beds underlying the Upper Tertiary of the plains bordering the Murray; Siliceous conglomerates and quartzite underlying Older Volcanic rocks, Gippsland.

FOSSILS.—Fauna: *Squalodon Wilkinsoni* (McCoy); *Physetodon Bayleyi* (McCoy); *Cetotolites*, 4 species; *Trigonia acuticostata* (McCoy); *T. semi-undulata* (McCoy), and *T. Howitti* (McCoy); *Tethya Newberyi* (McCoy), *Graphularia Robinæ* (McCoy). [Note.—This sea-pen is the supposed South Australian Tertiary Belemnite, referred to in various publications.] *Clypeaster Gippslandicus* (McCoy), *Haliotis Mooraboolensis* (McCoy); *Haliotis ovinoides* (McCoy); *Pleurotomaria Tertiaria* (McCoy); *Pecten*, various species; *Hinnites Corioensis* (McCoy), *Spondylus Gæderopoides* (McCoy); *Terebratula*, various species, including *Waldheimia Corioensis* (McCoy), *Cardium pseudomagnum* (McCoy), *Cucullæa Corioensis* (McCoy). Flora: *Cinnamomum polymorphoides* (McCoy); *Laurus Werribeensis* (McCoy); *Salisburia Murrayi* (McCoy), &c., &c.

(c) *Lower Teriary* (*Oligocene*).

(c) Emerald Green.

Grey clays, with septaria, near Schnapper Point and mouth of Gellibrand River.

PRINCIPAL FOSSILS.—*Limopsis aurita* (Sassi); *L. Belcheri; Pectunculus laticostatus* (Quoy); *Aturia Zic-zac* var. *Australis* (McCoy); *Nautilus; Voluta Hannafordi; V. anti-cingulata; V. strophodon* (McCoy); *V. antiscalaris* (McCoy); *V. macroptera* (McCoy); *Cypræa gigas* (McCoy); *C. gastroplax* (McCoy); *C. consobrina* (McCoy); *C. contusa* (McCoy); *C. platypyga* (McCoy); *C. platyrhyncha* (McCoy).

MESOZOIC.

(d) *Oolitic* (*Corbonaceous*).

(d) Burnt Sienna.

1. Thick and thin irregularly-bedded breccias, conglomerates, sandstones and shales, with seams of coal, Cape Patterson coal-field; South Gippsland; Bellarine; Cape Otway, and the Wannon.

FOSSILS.—Flora: *Tæniopteris Daintreei* (McCoy); *Podozamites Barklyi* (McCoy); *P. ellipticus* (McCoy); *P. longifolius* (McCoy); *Pecopteris Australis* (McCoy); *Sphenopteris*, &c. Fauna: Very rare, only two specimens found, *Unio Dacombi* (McCoy), and *Unio Murrayi* (McCoy). Both fresh-water molluscs.

COLOURS USED ON MAP.

2. Sandstones of Bacchus Marsh, containing *Gangamopteris angustifolia* (McCoy), *Gangamopteris spatulata* (McCoy), and *Gangamopteris obliqua* (McCoy), representing the Mesozoic Talchir beds of the Indian coal-fields.

PALÆOZOIC.

(e) *Upper Palæozoic.*

(e) Burnt Umber.

1. (? Carboniferous) Massive sandstones, in which fossils have not yet been found, Grampians.

2. Thick-bedded sandstones, coarse conglomerates, purple quartzose grits, grey flags, micaceous shales, and red or grey rubbly mudstones, with occasional interbedded layers of porphyry and melaphyre, representing the lava flows of the period altered by chemical action. The country between the Macalister and Mitchell Rivers, including the Avon River watershed in North Gippsland; Mansfield; Mount Tambo, and small tracts eastward from Mount Cann in the south-eastern portion of Victoria, and on the Mitta Mitta River.

FOSSILS.—*Lepidodendron Australe* (McCoy), *Archæopteris Howitti* (McCoy), *Cordaites Australis* (McCoy). The two latter are considered by Professor McCoy as indicative of Upper Devonian, the first being of Lower Carboniferous aspect.

(f) *Devonian.*

(f) French Blue.

Devonian limestones and calcareous beds, Mitta Mitta River, Bindi, Buchan; Micaceous sandstones and shales, Tabberabbera; Quartz-porphyry, felstone, &c., beneath or interbedded with the Buchan beds.

FOSSILS.—*Spirifera lævicostata, Favosites Goldfussi, Chonetes Australis* (McCoy) *Phragmoceras subtrigonum* (McCoy), *Asterolepis ornata* var. *Australis* (McCoy).

(g) *Upper Silurian.*

(g) Light Neutral tint.

Soft fine-grained micaceous sandstones and claystones, Melbourne; blue, grey, and yellow sandstones, mudstones, and calcareous breccias, Yarra basin; bluish-grey micaceous mudstones and sandstones, near Kilmore; Sandstones, schists, shales, limestones, conglomerates, Cape Liptrap, Waratah Bay, Stockyard Creek, and Turton's Creek, South Gippsland, and the country between the La Trobe and Macalister Rivers in North Gippsland, Wood's Point, Alexandra, and Heathcote; Encrinital limestones, Thomson River, Tyers River, and near Mansfield.

FOSSILS.—*Orthoceras Ibex* (Sow.); *O. Bullatum* (Sow.); *O. capillosum* (Bar.); *O. lineare* (Münst.); *O. striato-punctatum* (Münst.); *Cardium Gippslandicum* (McCoy); *Petraster Smythii* (McCoy); *Urasterella Selwyni* (McCoy); *Phacops caudatus* (Brong.); *Ph. fecundus* (Bar.); *Lichas Australis* (McCoy); *Homalonotus Harrisoni* (McCoy); and other *Trilobites* of various species; *Leptæna rhomboidalis, Spirifera plicatella, Spirigera reticularis, Trematospira liopleura* (McCoy); *Trematospira formosa* (Hall); *Pentamerus Australis* (McCoy); *Graptolites priodon* (Rs.); *Graptolites (Retiolites) Australis* (McCoy).

COLOURS USED ON MAP.

(h) Dark Neutral tint.

(h) *Lower Silurian.*

Blue slates, mudstones, claystones, coarse and fine sandstones, grits, and quartzites, Sandhurst, Castlemaine, Ballarat, Inglewood, Maryborough, Beechworth, and Crooked River districts; south-eastern portion of Gippsland; the head of the Murray, where limestone bands occur.

FOSSILS.—*Graptolites* (*Diplograpsus*) *palmeus* (Bar.); *Didymograpsus Headi* (Hall); *D. Thureaui* (McCoy); *D. quadribrachiatus* (Hall); *D. fruticosus* (Hall); *D. octobrachiatus* (Hall); *D. bryonoides* (Hall); *D. Logani* (Hall); *D. extensus* (Hall); *D. caduceus* (Salt); *D. gracilis* (Hall); *Phylograptus folium*, *Cladograpsus*, &c., of various species.

CRYSTALLINE (AZOIC).

(i) *Metamorphic Stratified Rocks.*

(i) Light Purple.

Metamorphised Lower Silurian rocks, east of Beechworth and at Stawell; Silky micaceous schists, mica schists, and gneiss of many varieties, passing from unaltered Silurian into metamorphic granite, Omeo, and Mitta Mitta districts; Chloritic talcose and micaceous schists and gneissose rocks, Upper Murray and River Glenelg.

IGNEOUS (VOLCANIC AND PLUTONIC).

(j) *Newer Volcanic.*

(j) Pink.

Ash, scoriæ, felspathic lavas, basalt, Tower Hill, Mount Porndon, Western plains; Keilor, Werribee, and Smeaton plains; Sebastopol Plateau, Mounts Buninyong and Warrenheip, Kyneton, and Malmsbury.

(k) *Older Volcanic.*

(k) Pink, barred.

Decomposed basalt, with concentric layers enclosing nodules of hard, bluish-black basalt, Melbourne, Emerald Hill, Kangaroo Ground, Berwick, Buln Buln, Narracan, Cape Schanck, Phillip Island, Pentland Hills, Russell's Creek, Tanjil, Bruthen Creek, Tarwin River, and Longwarre; Hard dense columnar basalt, Cape Schank, Dargo and Bogong High Plains, Gelantipy.

(l) *Trap.*

(l) Indian Red.

Porphyry, greenstone, diorite, &c., Snowy River, Dandenong Ranges, Mount Juliet, Dryden's Rock, Mount Macedon.

(m) *Granite.*

(m) Carmine.

East of Glenelg River, South of Stawell, Yowen Hill, Mount Korong, Terricks, Mount Alexander Range, Station Peak, Mount Eliza, Mount Martha, Strathbogie Ranges, sources of the River La Trobe, Beechworth, Mount Baw Baw, Wilson's Promontory, Cudgewa Creek, Tambo River, Genoa River; Syenite, Gabo Island.

Victoria presents no striking geological features of which counterparts cannot be found in other parts of the world. Of the formations given in the above list, some, as before stated, can with certainty be regarded, on palæontological evidence, as equivalents of well-known European strata; in the case of others, the evidence as to their precise position is meagre, but no doubt exists as to the accuracy of their general classification. Representatives of many of the subdivisions of European geology are wanting, or occupy very small areas, in Victoria, though, as regards some of them, Mr. Selwyn has pointed out that they may at one time have existed, but have been removed by the action of denudation.

Generally described, with reference to the physical configuration, Victorian geology presents the following main features :—1st. The Main Divide and its accessory systems of ranges north and south, constituting a great central longitudinal area of Lower Palæozoic rocks, through which protrude masses of granite and trappean rocks, and on which are overlying or flanking deposits of Upper Palæozoic, Mesozoic, and Tertiary ages. 2nd. The two great southern projections of Victoria, comprising the Western Port and South Gippsland Ranges on the east, and the Cape Otway Ranges on the west, of Port Phillip; also an area in the western district, south of the main road from Hamilton to Casterton, including a large portion of the drainage-area of the Wannon, and extending westward to the Glenelg River.

In all these areas the prevailing rock-formation is of Mesozoic age, though more or less overlaid by Tertiary sedimentary and volcanic layers. Wilson's Promontory, however, the extreme southern portion of the South Gippsland Ranges, consists entirely of granite; and from near Anderson's Inlet to the head of Corner Inlet the Silurian rocks bound the Mesozoic area on the south. A protrusion of the Silurian through the Mesozoic rocks occurs at Turton's Creek, some 10 miles north from Corner Inlet. A small area of Mesozoic rocks occurs near Bacchus Marsh. The total extent of country in which the Victorian rocks of this series prevail near the surface is about 4,000 square miles, but an additional area of nearly equal extent is probably concealed by overlying Tertiary deposits. 3rd. The low-lying or slightly-undulating tracks, consisting of sedimentary deposits of Tertiary and Post-Tertiary ages. Of these, the principal are :—The level country lying southward of the Murray River, from Wahgunyah to the western boundary of the colony, including the Wimmera district, and extending thence southward to the mouth of the Glenelg; tracts bordering the sea-coast, and extending for various distances inland, from the Glenelg to the Gellibrand; from Loutit Bay to Port Phillip; from between St. Kilda and Frankston across to Western Port; from the Powlett River to Anderson's Inlet

(here however, the recent deposits rest very thinly on Mesozoic rocks); from Corner Inlet to the Gippsland Lakes; the country bordering the latter on the north, and that extending eastward along the coast nearly to Cape Howe. 4th. The areas on which the Newer and the Older Tertiary volcanic rocks form the prevalent surface formation. Of the Newer Volcanic areas the principal is that lying westward of the meridian of Melbourne, bounded on the south partly by the Port Phillip coast and partly by the sedimentary Tertiary and Mesozoic areas lying southward of a line from Geelong to Portland; on the west, by a line from Portland to the Wannon; and on the north by the Palæozoic rocks of the spurs from the Main Divide. Between some of its leading spurs, strips of volcanic rock extend up to, and in some places over, the Main Divide, thus connecting the great volcanic areas lying to the south with those of lesser extent on the slopes towards the Murray.

Older Volcanic rocks of the Middle Tertiary period constitute the surface formation of various small areas in the Geelong district, around Melbourne, near Bacchus Marsh, Ballan, and between Lethbridge and Steiglitz; but they are more extensively developed in, or on either side of, the low-lying country which extends between Western Port and the La Trobe valley in Gippsland, and they also constitute the elevated plateaux known as the Dargo and Bogong High Plains. The low ridge near Drouin, previously described as forming the connexion between the mountain systems of the Main Divide and the South Gippsland Ranges, consists of decomposed Older Volcanic rock.

Throughout the colony, Tertiary sedimentary and volcanic cappings and outliers overlie the Mesozoic and Palæozoic rocks up to elevations of nearly 6,000 feet above sea-level. Tertiary deposits of marine origin are, however, only found below an altitude of 1,000 feet above the sea; any Tertiary deposits above that level show evidence of being due to fluviatile or lacustrine agencies, at any rate so far as the existing arrangement of their materials is concerned.

Having so far given a general description of the main geological features, as related to the physical geography of Victoria, the formations themselves will now be described in ascending sequence, so as to portray, if possible, the natural operations and changes that have taken place from Palæozoic times to the present.

CHAPTER III.

Granite—Localities; Physical Character and Vegetation of Granitic Areas. Mineralogical Characters—Stratigraphical Position and Relations to Palæozoic Rocks. Trappean Rocks—Mineralogical Characters of, and Areas occupied by.

LOCALITIES.

Granite occurs in protruding masses forming isolated areas of varying extent throughout the colony.

To quote from Mr. Selwyn's work:—" It does not occur along any defined axis or line, nor has it any physical connexion with the main geographical axis of the country, but forms isolated groups of hills, such as Station Peak, Mount Eliza, Arthur's Seat, Wilson's Promontory, &c., on the south, and Mount Alexander, Mount Tarrangower, the Terricks, Mount Korong, Mount Beckworth, and others on the north.

Some of these—as Station Peak, the Granite Range of the Anakies, the Terricks, some points on the Avoca Plains, and a solitary outcrop west of the Glenelg River—are entirely surrounded by level Tertiary or Volcanic country, and are not connected by any surface ridge with the main mountain system.

On the Main Divide itself, a portion west of Ararat, Lar-ne-Gerin, Mount Buangor, a portion north of Lancefield, Mount Disappointment, Mount St. Leonard to Mount Arnold, and eastward of Mount Leinster, between Mounts Tambo and Cobberas, are the only instances where granite constitutes the crest of the Main Divide, and the greatest lengths of these granitic areas are usually across, instead of along, the axis of the range. In most cases, the granite outcrops constitute portions of the minor systems of ranges formed by the leading northern and southern spurs from the Main Divide. Of the two largest areas of granite, one is that which extends between Reedy Creek and the King River, and includes the Strathbogie Ranges; the other is that consisting partly of granite and partly of rocks classed on the Geological Sketch-map as Trappean, which extends from the Main Divide, between Mount St. Leonard and Mount Arnold to the Goulburn on one side, and on the other to the Yarra, where it is connected by a narrow belt with another large granitic area extending along the Southern Spur from Mount Baw Baw to the head of the La Trobe, and thence to near Dandenong.

Besides those already mentioned, the following are the principal tracts where granite occurs as the surface rock:—An area surrounded by metamorphic rocks between the Wannon and the Glenelg, and several localities in the Grampians; Yowen Hill, Mounts Gowar, Kerang, Egbert, and McIntyre's Ranges, near Kingower; between Ararat and Stawell; small outcrops near St.

Arnaud; Mount Bolton; from Elphinstone, through Ravenswood, to Tarrangower; eastward of Ballarat; Futter's Ranges, near Wangaratta; Eldorado to Beechworth; Myrtleford to Yackandandah; Murray River, eastward of Mitta Mitta River; the Buffalo Ranges; The Brothers, near Lake Omeo; Tambo River; Swift's Creek; Dargo and Mitchell Rivers; Snowy River, Mount Ellery, Genoa River, Ram Head, Howe Hill, Gabo Island, Tamboon Inlet, Point Everard, the Bogong Mountains, and a small outcrop in the head of a branch of the Avon, in Gippsland; besides a number of minor occurrences, which will be found indicated upon the Geological Sketch-map.

Physical Character and Vegetation of Granitic Areas.

The physical aspect presented by the granitic areas is usually of a rugged character, except where, in the less elevated tracts, the outlines have been softened by denuding influences. In the higher mountains, the weathering of the softer portions of the granite has left, jutting from the soil, immense bare portions of the harder rock, upon which great egg-shaped masses frequently rest on end, and appear as though a touch would overturn them. (Figs. 1 and 2.)

The Wilson's Promontory mountains abound in such "tors," which are generally characteristic of granite country in this and other parts of the world.

The granitic areas in Victoria, as a rule, are covered with an inferior soil for either agricultural or pastoral purposes, and support only small or medium-sized timber; but in some localities, where the conditions are favorable and the climate humid, they sustain a gigantic forest growth, with an almost impenetrable scrub of smaller vegetation.

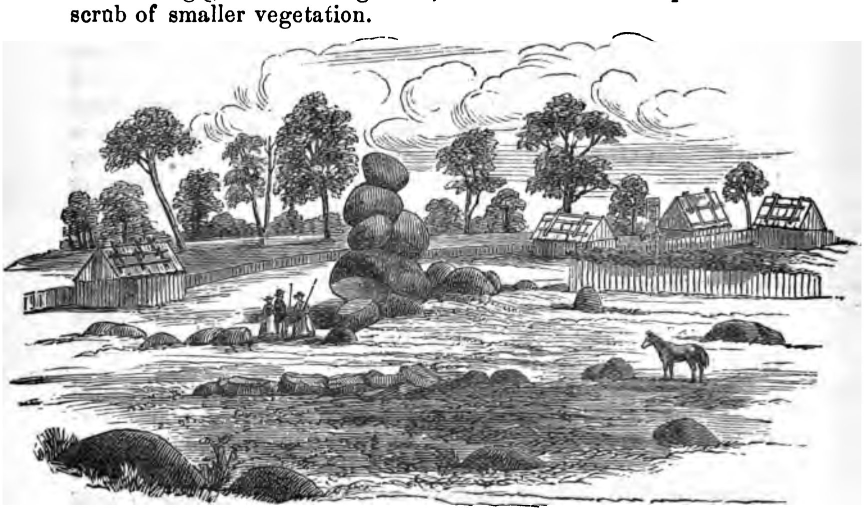


Fig. 1.—Granite Tor, Sheep Station Creek, Beechworth.

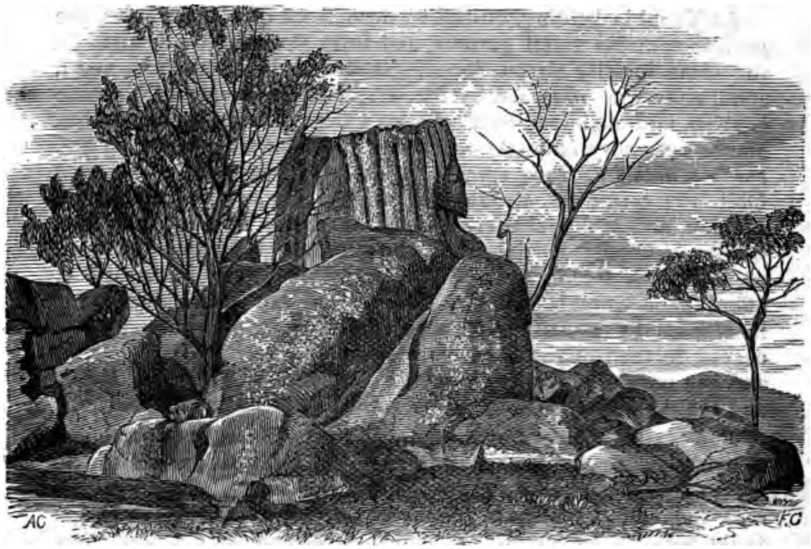


FIG. 2.—GRANITE ROCKS NEAR THE ANAKIES.

In the valley of the Watts River, and on the southern slopes of Mount Baw Baw, grow some of the loftiest trees (Eucalypts) in the world, surrounded by a dense growth of hazel (*Pomaderris apetala*), musk (*Aster argophyllus*), dogwood (*Senecio Bedfordii*), sassafras (*Atherosperma moschatum*), various pittosporums, and numerous other shrubs and tree-ferns of several species. The native beech (*Fagus Cunninghami*), one of the most beautiful of our forest trees, attains its greatest perfection in these localities.

MINERALOGICAL CHARACTERS.

The typical granite of Victoria is the normal coarse to fine crystalline-granular ternary compound of quartz, felspar, and mica, which constitutes the typical granite of other parts of the world. Nearly all other known varieties are also met with—as *binary granite*, composed of quartz and felspar; *griesen*, composed of quartz and mica, and devoid of, or very poor in, felspar; syenite granite, porphyritic granite, &c. The felspar varies in colour from white to deep pink; the quartz is vitreous, white or grey in colour, and from nearly transparent to opàque; the mica is black, yellow, or white, and the three minerals occur in variable proportions. Black tourmaline (schorl) is frequently present as an accessary mineral. In the granite of Wilson's Promontory, Beechworth, Mount Alexander, &c., prisms of schorl occur, singly or aggregated in radiating masses. Dykes of fine-grained schorlaceous granite, accompanying quartz veins, intersect the ordinary granite in the first-named locality; and numerous other varieties, in the form of dykes, traverse the main granite masses.

At Yanakie landing, on the western shore of Corner Inlet, the granite contains small garnets, and from the granitic detritus in the same locality zircon, topaz, green and blue sapphire, and a small ruby were obtained by Mr. W. Miller, manager of Yanakie Station, and examined by Professor Ulrich, who also enumerates, among accessory minerals occurring in Victorian granite, *tin ore, epidote, chlorite, fluor spar,* and *amethyst,* at Beechworth and Chiltern; *columbite,* at Maldon; *molybdenite,* at Yackandandah, Maldon, and Moliagul; *iron-glance,* at Mount Korong; and *iron pyrites,* generally distributed. The granites of various localities, as Harcourt, Gellibrand's Hill, Gong Gong, near Ballarat, &c., afford good durable building stones, and are also valuable for monumental purposes. A very beautiful syenite granite, composed of red felspar, quartz, and hornblende, occurs at Gabo Island, and has been used in the General Post Office, the Custom House, and the Australasian Insurance Company's office, in Melbourne.

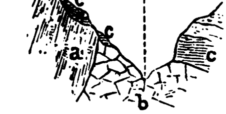
The typical Older Plutonic granite and kindred rocks unquestionably occupy the lowest stratigraphical position, and constitute here, as they probably do throughout the world, the prevailing rock foundation. Their appearance at the surface is evidently due to the removal, by denudation, of once superincumbent sedimentary strata. Geologically, however, these older hypogene rocks are younger than the Palæozoic strata of Silurian age, but older than those classed as Upper Palæozoic. The grounds for this opinion are, that whereas the Upper Palæozoic rocks, where found resting on the granite, are unaltered, and their granite foundation appears to have been as we now see it at the time of their deposition, the Lower Palæozoic rocks are invariably more or less metamorphosed near their contact with, and frequently contain injected veins of, the granite, showing that since their deposition the granite has been in a heated and plastic, or possibly a molten, condition. (Fig. 3.)

Another marked feature is that the granite intrusions do not appear to be connected with the folding process to which the Silurian rocks have been subjected, and to which is due the normal high rate of inclination of their layers. That process would appear to have taken place prior to the invasion of the sedimentary strata by igneous masses, as we find in many cases that the strike of Silurian strata abuts directly on the granite, and in others that the dip of the strata is against, instead of with, the surface slope of the granite. Evidences of the intrusive character of the granite to a certain extent are, however, visible in many places, in the

FIG. 3.

Sketch-section illustrating relations of Granite, Silurian, and Upper Devonian rocks, Mount Hump Creek, branch of Avon River.

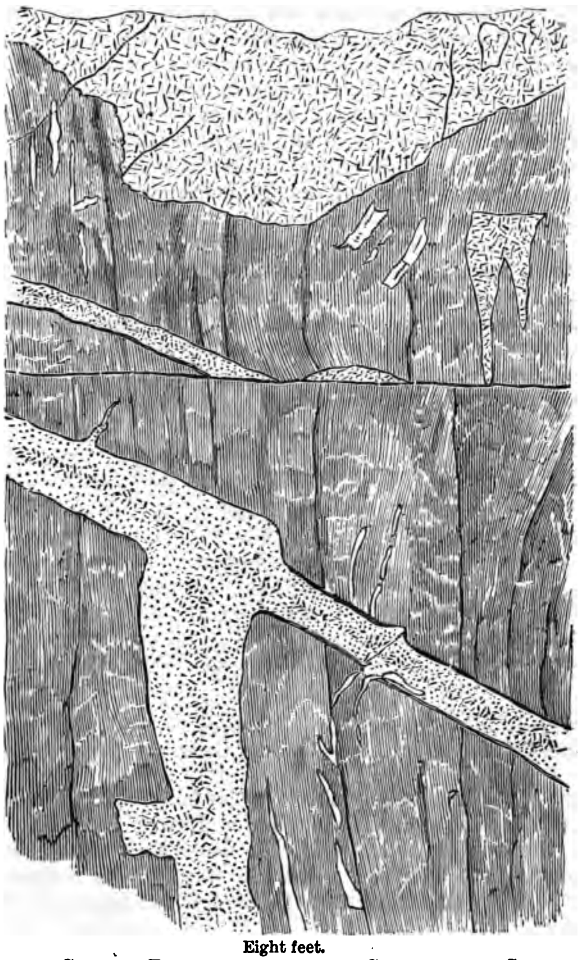
Branch of Mount Hump Creek.



a Silurian. *b* Granite
c Upper Devonian.

locally-contorted and crumpled state of the Silurian strata near their contact with the former.

According to the description given by Mr. A. R. C. Selwyn, of the country east of the Snowy River, the summits of many of the hills and ranges there consist of nearly vertical Silurian slates



Eight feet.

FIG. 4.—GROUND PLAN OF CONTACT OF GRANITE AND SILURIAN, LOWER THREE-MILE CREEK, BEECHWORTH.

The granite is a felspathic ternary compound. The granite veins cut sharply across the indurated Silurian strata. They are fine-grained at the sides, but coarsely aggregated in the centre, and with strings and patches of yellowish orthoclase. Two sets of vertical joints traverse the granite. Main joints E. to W. The indurated Silurian rocks are dense and crystalline, blackish or bluish-black in colour, and marked by fine stripes following the line of strike of the beds. Dip. S. 63°–65° W. at about 80. Patches and strings of quartz found in both rocks.

and sandstones, resting on edge upon the granite which appears at the base of the slopes. These facts indicate that the presence of the granite cannot be immediately associated with any idea as to the nature of the forces which caused the general tilting, folding, and corrugation of the Lower Palæozoic rocks; and also that the granite, as we now see it, could not have been the foundation on which those rocks were originally deposited.

The inferences are that after, or perhaps during, the plication, by whatever causes, of the Silurian rocks, an access of heat caused the fusion of their foundation at great depths below the then surface; that this fused and plastic mass invaded and partly absorbed the lower edges of their folds; that beyond the limits of such actual transmutation of the sedimentary strata into portion of the fused granitic mass, the former were metamorphosed by heat and other agencies combined for a greater or less distance from the igneous mass; and that after this mass had cooled and consolidated into granite under great pressure, and a great depth below the then surface, the action of denudation during subsequent periods removed portion of the superincumbent strata, and laid bare its more prominent projections. (Figs. 4 and 5.)

FIG. 5.—SECTION SHOWING CONTACT OF GRANITE AND SILURIAN.—TAIL RACE OF ROCKY MOUNTAIN GOLD SLUICING COMPANY, BEECHWORTH.

Much of our granite may, therefore (as indicated by Mr. Selwyn), be regarded as completely transmuted Lower Palæozoic strata; but as this subject will be further dealt with in describing the metamorphic stratified rocks, the Plutonic igneous rocks allied to granite, but of somewhat different mineral combinations, will first be noticed.

Among the areas represented as "trap" on the Geological Sketch-map, the rocks in three, namely, those of Mount Macedon, the Dandenong Ranges, and Mount Juliet, besides others of minor extent, appear to be intimately associated with the ordinary granites, though the true relations of the rocks have not yet been properly investigated. In all three instances there seem to be no clearly-defined lines of demarcation between the rocks classed as

"trap" and the adjacent granites, while in some places a gradual passage from one to the other, as regards mineral composition, is observable, and the different forms appear to blend with one another as though they were simply rocks of varying mineralogical structure belonging to the same general mass. The trappean area of Mount Macedon, on the Main Divide, as shown upon the geological map of the locality, is partly bounded on the east by granite, apparently not presenting any abnormal mineralogical character, judging from the notes upon the map, which indicate coarse and fine-grained varieties, with large and small plates of mica, and, occasionally, schorl. Between this granite and the "trap" only an approximate boundary line is indicated. The rock of Mount Macedon itself, and of several other places in the same area, is described in the notes upon the map as "dark-grey felspar trap, granular, and not at all porphyritic." Mount Diogenes, another point on the Main Divide, north-eastward from Mount Macedon, is described as a dome-shaped mass of rock of a porphyritic character, *i.e.*, containing disseminated isolated crystals. A specimen from here is described, in a catalogue published by Mr. Selwyn in 1868, as consisting of a light-coloured granular base, with black specks, probably hornblende, and enclosing crystals of orthoclase felspar and quartz. A general note describes the "trap" of the northern portion of the area as displaying "a soft ash-coloured earthy and amygdaloidal character, whilst that of the southern (near the granite) is dark-grey, granular, and crystalline." Other varieties of "felspar trap," "felspar porphyry," and "granitic porphyry," are described in Mr. Selwyn's catalogue as having been obtained from the Mount Macedon Range, and from neighbouring trappean areas. Specimens lately examined show a mineralogical composition, justifying the application of the term "syenite porphyry" to some of the Mount Macedon rocks.

The "trap" of the Dandenong Ranges is shown on the Geological Sketch-map as being bounded on the south by granite, and on the other sides by Upper Silurian rocks. Specimens of "ternary granite" and syenitic porphyry, from near Dandenong, and of "micaceous felspar trap," "felspar porphyry," and "syenitic felspar porphyry," from the Dandenong Ranges, are described in Mr. Selwyn's catalogue.

The Upper Silurian rocks near Lillydale show considerable metamorphism near their contact with the "trap" in the northern part of the Dandenong Range, indicating a heated condition of the trappean mass subsequent to the deposition of the Silurian strata.

The great trappean area, of which Mount Juliet is the centre, and which also includes portion of the Main Divide, between Mount St. Leonard and Mount Arnold, is more or less bordered by granite, which forms intervening belts between it and the Silurian rocks.

So far as this tract has been superficially examined, no arbitrary line of demarcation between the granite and the trap can be laid down. The general characters displayed by the latter are various, but of some typical samples I am fortunately able to quote the following descriptions, supplied by Mr. A. W. Howitt, F.G.S., who has made the microscopical investigation of rock-structure one of his special studies, and who has kindly examined for me a large number of igneous rock-specimens:—

"MASSIVE TRAP, NEAR HEALESVILLE.

"Ground-mass, micro-crystalline, consisting of felspar and quartz. In it are—(1) Crystals of quartz; (2) Orthoclase crystals. No triclinic felspar observable, but a little mica (? muscovite), which is quite subordinate. In composition, this is a quartz-felsite."

Another specimen of trap rock from the Watts River, near Healesville:—"This is a quartz porphyrite (hornblendic)."

No. 1 specimen, from north of Yarra River, opposite Warburton.—"Ground-mass, micro-crystalline, of quartz and felspar and a little magnetite. In it are—(1) Felspar, mostly plagioclase; (2) Chlorite pseudomorphs after hornblende; (3) Masses of felsitic ground-mass. This is a hornblende porphyrite."

No. 2, north of Yarra River, opposite Warburton.—"This rock is in character between a quartz porphyrite and a quartz felsite, there being both orthoclase and plagioclase felspars."

Two remarkable belts, resembling enormous dykes, are indicated as trappean on the Geological Sketch-map. One forms the summit of the Mount Staveley Range, south from the Grampians, between Wickliffe and Dunkeld, and protrudes through Lower Silurian rocks. Judging from a hand-specimen, the rock is a felspar porphyry, but I have not had an opportunity of obtaining information from personal observation as to the extent and character of the outcrop.

The second forms the ridge of the Mount Camel Range, 10 miles north from Heathcote, and the rock consists there of a dark, dense, hornblendic greenstone diorite—hornblende rock. It is in the same line of strike with a large dyke of fine granite which passes through Heathcote.

Still further to the south, in the same direction, another long outcrop of greenstone diorite forms a range to the east of Lancefield. The entire belt, from Mount Camel to Lancefield, follows approximately the apparent boundary line between the Lower and Upper Silurian rocks.

Mr. Norman Taylor describes the rock near Lancefield as being very variable in its mineralogical character, some varieties being greenish-black and dense (aphanitic), others light-green and porphyritic, and others nearly black, crystalline, and very hornblendic.

This greenstone was once largely used by the aborigines for manufacture into stone-tomahawks and other implements. About a mile north-east of Mount William, near Lancefield, is the site (locally known as the native tomahawk quarries) whence they principally obtained the stone.

Were a number of samples collected and microscopically examined, there is no doubt that a very great variety of mineralogical structures and combinations would be shown to exist in these trappean rocks; and, before adopting conclusions as to their relation to the ordinary granites, further careful study will be necessary. Two probable solutions of the problem suggest themselves. The first, is that the "trap" rocks of the localities referred to are simply portions of the granitic mass, and, like it, of Lower Plutonic origin, but that from some difference of composition, or from having cooled under different conditions, their mineralogical structure assumed forms different from those common among the ordinary granites. The second, is that they are intruded or irrupted masses through, or re-fusions of, the granite subsequent to its first cooling, and that they indicate the localities of deep-seated volcanic activity during Palæozoic times, in which case they might be classed as Upper Plutonic.

Illustrative examples of the latter theory are described by Mr. A. W. Howitt, in his work entitled "The Diorites and Granites of Swift's Creek and their Coutact Zones, with Notes on the Auriferous Deposits."

In the work referred to, Mr. Howitt gives an exhaustive description of the petrological and mineralogical characteristics of the igneous and metamorphic rocks of Swift's Creek, a tributary of the Tambo River, and shows that after "regional" metamorphosis of the Silurian rocks of that locality, and at the line of passage from the metamorphic into the normal Silurian rocks, intrusions of granite and diorite took place, which effected around them a still further metamorphism ("contact" metamorphism) of the slates and schists. Mr. Howitt draws the conclusion that these intrusions took place after the close of the Silurian, and before commencement of the Upper Devonian, periods, and were probably connected with the volcanic activity of that time. These Newer Plutonic rocks will, however, be referred to when describing the rocks of the Devonian period.

On the northern margin of the valley of the Wannon is an area occupied by igneous rocks, classed as "trap," of the true position of which, whether Older or Newer Plutonic, intrusive or contemporaneous (*i.e.*, the lava flows or injected sheets of their period), nothing is known. Their character varies in different localities. A few miles eastward from Casterton, a dark dense greenstone is exposed in the bed of McPherson's Creek. It is

in some places undecomposed, and in others decomposed to a condition resembling the decomposed Older Volcanic rocks of the Tertiary period. On the slopes of the hills above, the rock appears slightly decomposed, and exhibits a curiously-blended mixture of portions of a dense aphanitic structure, with others of a porous vesicular character, almost resembling pumicestone.

North of Coleraine, one variety is a dark, dense, flinty, and exceedingly fine greenstone or Labradorite diorite. Another description is wackenitic in character, resembling an altered volcanic mud, rather soft, yellowish-brown, and highly felspathic, with porphyritically-included crystals of felspar; sometimes vesicular, and containing in the vesicular cavities a soft, greenish, clayey material (lithomarge). In its composition, this rock also approaches phonolite.

At the Nigretta falls, on the Wannon, the rock is a typical quartz and felspar porphyry of a brownish-pink felsitic base, with embedded quartz and felspar crystals. At Cavendish, further eastward, is a dark greenish-grey, dense, and much-jointed rock, apparently aphanite, not showing porphyritic structure. From an outcrop in the Grampians, coloured as granite on the Geological Sketch-map, specimens were obtained and described, in Mr. A. R. C. Selwyn's catalogue of 1868, as granite felspar-porphyry, syenitic porphyry, and felstone porphyry. So little is known of the geology of this portion of the colony, that a mere reference to the lithological character of the rocks is all that can at present be given.

On the northern slopes of the Barrabool hills, west of Geelong, occurs a small area of what Professor Ulrich describes as "diallage rock"—a coarsely-crystalline granular mixture of light-green Labradorite, and of a dark-green augitic mineral, which, according to its lustre and cleavage, is diallage. This Plutonic mass is surrounded by Mesozoic rocks, but is evidently older than the latter, from the fact of beds of Mesozoic conglomerate in the neighbourhood containing pebbles of the diallage rock. On accounts of its colour and susceptibility to fine polish, this rock is well adapted for ornamental purposes, though very hard to work.

The general conformity of the ordinary Lower Plutonic granites to one type, in all parts of the world, indicates a general similarity if not a synchronism of the conditions under which they attained their present structure. Their varieties in character and arrangement of mineral constituents may be justly attributed to—(1) local differences as regards the presence of those constituents in greater or less quantity, the entire absence of some of them, or the addition of other than the common minerals; (2) differences in the character of the sedimentary rocks, which, in a transmuted form, have entered into the composition of the granites; (3) differences of heat, rates of cooling, intensity of chemical

and hydrothermal action, and of depths below the surface and pressure of superincumbent rocks at which these agencies were in operation.

The greater number of varieties of mineral composition and arrangement, hardness, general structure, texture, &c., noticeable in the trappean or Newer Plutonic rocks, indicates that the conditions under which these combinations were effected, and the cooling of the rock-masses took place, were more varied than in the case of the Older Plutonic granites.

Re-fusion may also in many cases have caused an altered arrangement of component minerals.

Leaving the remaining groups of igneous rocks for consideration in connexion with the sedimentary deposits of the geological epochs to which they belong, the Lower Palæozoic and metamorphic (azoic) sedimentary rocks will now be noticed.

CHAPTER IV.

Lower Palæozoic and Metamorphic (Azoic) Rocks. Silurian Rocks—geographical extent. Metamorphic Rocks—areas respectively occupied by Lower and Upper Silurian Rocks; leading characteristics; general theory as to origin and metamorphism. The Metamorphic Rocks—"regional" and "contact." Unaltered Lower Silurian Rocks—fossils. Upper Silurian Rocks—fossils. Physical Character of Silurian Country.

The Lower Palæozoic rocks of Victoria have been referred, upon clear palæontological evidence, to the Lower (Cambro) Silurian and Upper Silurian groups.

With the exception of the Lower Cambrian and Laurentian rocks, not yet recognised, and probably not occurring in Victoria, the Silurian strata are the oldest in the world that contain vestiges of organic life. As surface or underlying rocks, they occupy the greater part of Victoria, from the sea-coast to elevations exceeding 6,000 feet; from the Glenelg to Cape Howe, and from Cape Liptrap to the Murray, constituting the prevailing rock-formation of the Main Divide mountain system, and the bed-rock of the entire colony, except in places where the subjacent granites and trappean rocks have been laid bare. Taking a broad view of the Silurian system generally, it may be described as extending across the colony in a series of sharp alternate anti-clinal and synclinal undulations, which form the minor folds of a great, more or less broken, synclinal trough, whose edges appear at either side of the country.

Mr. A. R. C. Selwyn estimated the total thickness of the series, making allowance for the recurrence of the same bands, at not less than 35,000 feet.

The metamorphic rocks of the series, among which may possibly be representatives of the Lower Cambrian and Laurentian groups, appear between the Wannon and Glenelg Rivers westward of the Grampians—where they constitute the rock-formation of the western terminal spurs of the Main Divide—and in the north-eastern or Omeo district, where they prevail over a considerable length of the Main Divide and the country extending north and south from it.

In both the districts mentioned, the rocks of this group are metamorphic as regards lithological character, and are so indicated upon the Geological Sketch-map; but, in geological age, they appear to be Silurian as regards the period of their deposition.

The normal or unaltered Lower Silurian rocks form the prevailing rock-foundation from westward of Ararat to a line from Melbourne to Heathcote; eastward of that line, and occupying the central eastern portion of the colony, appears the Upper Silurian group, the rocks of which are clearly recognisable as far eastward as a line from the Macalister River, in Gippsland, to Benalla. The Silurian rocks eastward from that line have been indicated on the Geological Sketch-map as Lower Silurian, but, from recently acquired information, it appears likely that they are Upper Silurian as far eastward as Beechworth.

The leading characteristics of the Lower Palæozoic rocks generally, in Victoria, are the normal N.Wly. to N.N.Ely. strike, and the high rate of inclination of their bands, caused by the crumpling or folding process to which they were subjected at a date probably not long subsequent to their deposition, as we find nearly horizontally-bedded rocks of Upper Palæozoic age resting on the abraded up-turned edges of the nearly vertical Silurian strata.

A statement of the generally-accepted working theory as to the causes of this plication of the strata, and of other processes to which they have been subjected, may not be out of place here, for though familiar to most students of geology it may not be so to the general reader, and will serve to elucidate foregoing remarks as to the Plutonic rocks. In the first place, it is now recognised as a demonstrated fact that most stratified rocks are the results of the gradual deposit by the sea of matter once held by it in suspension or solution, and originally derived from the disintegration of pre-existing formations, and that, by the action of pressure, heat, chemical agencies, or whatever causes, these once soft and plastic sediments were indurated and converted into rock-masses. The results of astronomical and geological investigations combine to justify the belief that this earth was once in a state of intense heat, and in the condition of a molten mass environed by an atmosphere of gases; that, gradual cooling, allowed the consolidation of a crust on the surface of the heated bulk, the formation of water by the union of its component gases and the descent of that water on the surface of the globe; and that from that epoch commenced the work of deposit, denudation, and re-distribution of particles by aqueous action that has ever since been in unceasing progress.

Whether this theory be correct in detail or not, it is very evident that a hardened crust of some description, on which the first aqueously-deposited strata could be laid down, must have been in existence, and that during the formation of these earliest sedimentary rocks conditions were present which do not obtain with regard to the deep-sea deposits now in progress.

The earth was still in a highly-heated condition and of greater bulk than now; the water probably covered the entire surface, and

continued for a long time after its descent in a state of ebullition, and was charged with a greater amount of mineral matter in solution than at present. Natural chemical operations were in a state of intense activity, aided by the heat.

With the abatement of the surface-heat, the lower forms of marine organic life appeared, and their remains were entombed in the accumulating sediments which were laid down by the water upon the then thin crust of consolidated igneous matter.

The continued cooling process, and the reduction of the expanding heat-force which had partly counteracted the attraction of gravity, caused general shrinkage of the interior bulk; the hardened crust, with its superimposed sedimentary layers, drawn centrewards by the attraction of gravity from within, and impelled by the atmospheric pressure from without, naturally sank, and in sinking became folded and corrugated through having to occupy a decreased area. It is easy to conceive that during such process the downward undulations of the sedimentary layers, together with the igneous crust on which they had been deposited, would be lowered to within the influence of the heated nucleus, by which the lower edges and folds of the broken and plicated strata would be fused, partly absorbed, and altered. Distinct from the heat of the internal mass, which would only radiate a short distance, heat generated by motion would no doubt play an important part in effecting alterations of the plicated strata. Such movements were probably repeated from time to time at different parts of the earth's surface as further contractions took place. Besides movements resulting from general shrinkage, extraordinary pressure in one locality would cause an upward thrusting in another of the heated material, and the local transmutation thereby of the sedimentary rocks at the planes of contact.

It is very improbable, as pointed out by Professor Jukes in his Manual of Geology, that the primeval igneous crust consisted of granite, as such a rock would not be formed at the surface. Every vestige of the original crust has, in all likelihood, been re-melted and transmuted along with portions of the superincumbent sedimentary layers, and the granite, as we now see it, is the product of the melted mass which has cooled at great depths beneath the surface.

The above is at present the generally-accepted explanation as to the cause of the highly contorted and plicated state of the Older Palæozoic rocks, and the previously noticed phenomenon of their being frequently found resting on edge against the granite, as well as their metamorphosed condition for a greater or less distance from their planes of contact with the latter. The outlines of the theory as to origin having been so far enunciated, the Lower Palæozoic strata will now be more fully described, commencing with the metamorphic stratified rocks or crystalline

schists, classed as Azoic from the non-discovery hitherto of any fossils in their layers, though probably of Silurian age as regards their deposition.

METAMORPHIC ROCKS AND CRYSTALLINE SCHISTS.

Strictly speaking, all rocks composed of consolidated sedimentary deposits have been metamorphosed, inasmuch as their present condition is very different from what it was when they were first laid down in the form of silt, mud, sand, gravel, or precipitates, owing to the long-continued influences of pressure, heat, hydrothermal and chemical action; but the term "metamorphic" is here specially applied to certain groups of rocks, which appear to be the extreme products of this process of transmutation, and may be divided, as indicated in Mr. A. W. Howitt's work, previously referred to, into two kinds, "regional" and "contact."

The character of the first appears to be the result of long-continued metamorphic action radiating for great distances and gradually decreasing outwards from central foci. The precise nature of this action is still a matter of conjecture, but it appears to have been different from that which operated in the case of the "contact" metamorphic rocks in which the metamorphism is more local, and is evidently the effect caused by intrusions or invasions of the sedimentary strata by igneous masses, the influence of which did not extend very far and did not continue long in activity.

In fact, it is frequently found that the "regional" metamorphic rocks have been further and subsequently affected by "contact" metamorphism at their planes of junction with the granites and trappean rocks.

Of the two great "regional" metamorphic areas in Victoria, one is situated between the Wannon and Glenelg Rivers, westward of the Grampians, and includes the western terminal spurs of the Main Divide; the other is a tract of country in the north-eastern portion of the colony lying to the eastward of the Dividing Range between the Ovens and Kiewa Rivers, and of the heads of the Dargo River, extending southward of the Main Divide into the Tambo Valley, and eastward and northward to the Murray.

The rocks of the western area have been but little examined, and are very much overlaid by newer deposits; they occur exposed between the Wannon and Glenelg Rivers, north of the former and south and east of the latter. They surround a central mass of granite, to which their relation has not yet been studied, and consist principally of brown and white fine to coarse quartzites, some curious forms of granulite, foliated micaceous, talcose, chloritic, and serpentinous schists, and schists composed of alternating quartzose and argillaceous laminæ. They are unconformably overlaid by

the Upper Palæozoic sandstones of the Dundas Range, and are, therefore, clearly of older date, probably Silurian, or possibly of the Cambrian or Laurentian series. No actual gold workings have been opened, though small prospects of gold are reported to have been obtained from both alluvial deposits and quartz reefs within this area.

The metamorphic rocks of the North-Eastern district, which includes Omeo and other gold-fields, afford fine opportunities for examination, as gradations of structure are in many places easily traceable on the surface, unconcealed by any overlying deposit. The best observed tract is that extending from the Dargo River, near Mayford, to Mount Bogong in one direction, and to Omeo and Mount Tambo in another. On the western slope towards, and in the bed of, the Dargo River at Mayford, are the normal Silurian slates and sandstones.

From Mayford, towards Bogong or Omeo, a gradual change is observable in their character; the ordinary rocks pass into silky micaceous schists, followed by mica-schist, gneiss, and gneissose granite, finally merging into granite which yet shows occasionally a rudely-schistose structure, indicative of its having been once in the form of a stratified rock. Similar gradations are observable all round this metamorphic area, of which the Bogong Range is the most central granitic mass, though there are several other granite tracts that appear either to represent foci whence radiated the metamorphic influences which altered the Silurian rocks, or, at all events, to be the extreme results of these influences. Besides the common gneissose and micaceous schists, there are in the Chiltern, Omeo, Bogong, and Mitta Mitta districts many varieties of metamorphosed stratified rocks, such as nodular micaceous schist, chiastolite schist, leptynite schist containing garnets, hornblende schist, and others.

In some cases, the altered rocks agree in general direction of strike with the unaltered, but in others the former show extreme contortion, and their strike varies greatly from the normal direction. Numerous dykes and injected masses of porphyry, greenstone, diorite, &c., showing great diversity of mineralogical structure, intersect the metamorphic schists throughout the Omeo district. At Stawell, and near Ararat, occur small belts, about a mile in width, of metamorphic rocks, consisting—as described by Mr. Norman Taylor in his report upon the Stawell gold-field (Geological Progress Report, No. II.)—of foliated gneissose schists, passing into true gneiss, composed of alternating layers of felspar, hornblende, and quartz, hornblendic gneiss, and other varieties.

Some of the metamorphic rocks of Stawell, however, differ very little from the normal Silurian strata, except in being generally more indurated and foliated than the latter.

"Contact" Metamorphic Rocks.

The "contact" metamorphic rocks occupy zones fringing nearly all the granitic and trappean rock-masses where the Palæozoic sedimentary rocks come in contact with them, and sometimes, though by no means invariably, form the walls of dykes or other smaller igneous intrusions.

They very much resemble the "regional" metamorphic rocks in variety of lithological character, and exhibit the same gradations of metamorphism, though generally in a less degree, and with the exception that distinct boundary lines can be traced between them and the granite, when the latter is invasive or intrusive, as distinguished from the "regional" metamorphic granite.

The alteration often does not consist in more than induration, or the addition of a spotted or slightly nodular character to the ordinary slates, &c. For instance, hand specimens from the junction of the granite and the Silurian rocks at Maldon can be obtained, showing granite on one side and indurated siliceous sandstone on the other. Near the contact of the trappean rocks of Mount Camel, north of Heathcote, the Upper Silurian rocks have been metamorphosed for a short distance to the conditions of jasper, chert, quartzites, and siliceous breccias.

Breccias, made up of angular fragments of altered sandstone cemented by siliceous matter, occur in places near the granite boundary at Beechworth. At the junction of the trappean and Upper Silurian rocks near Lillydale, the latter are much indurated and in some places metamorphosed into schistose quartzites.

At the head of the Buchan is a metamorphic calcareous schist acutely corrugated, and on the Limestone River occurs a band of nearly white marble. The "contact" metamorphism rarely extends more than half-a-mile, sometimes only a few yards, from the granite or trappean boundaries, and in some cases has evidently been effected at a date subsequent to that of the "regional" metamorphism, as shown in Mr. A. W. Howitt's work, already referred to, on the geology of Swift's Creek. It may, therefore, be justifiably assumed that there were two phases of metamorphic action operating at different epochs.

In the earliest of these, the action was long-continued and far-penetrating in its effects, and the blending or transmutation of the sedimentary rocks with or into the plastic igneous masses which subsequently cooled in the form of granite took place by slow gradations of change. It is doubtful, too, whether the heat was evolved from those igneous masses or was locally engendered by the movements of the rocks themselves.

In the second, or later, era of metamorphism, the transmutation of portions of the stratified rocks into granite was more complete,

but ceased at more abruptly defined limits, while the partial metamorphism of the former did not extend very far outside the limits of complete transmutation.

Further investigation would no doubt show the existence of various stages, intermediate between "regional" and "contact" metamorphism, among the zones of altered rocks surrounding granite areas lying between the extreme eastern and western metamorphic areas of Victoria; but, in the present state of knowledge, only the two distinctions already noted can be indicated with any degree of certainty.

The Unaltered Lower Silurian Rocks.

The term "unaltered" is here used simply to designate those Silurian rocks which do not exhibit in their structure the distinct effects, as above described, of "regional" or "contact" metamorphism.

The Lower Silurian rocks prevail westward of a line from Melbourne to Heathcote, and form the "bed-rock" or "bottom" of all the western gold-fields. On these rocks lie the most extensive and richest auriferous gravels, and traversing them are the gold-bearing quartz reefs to which Victoria so largely owes her present high position as a mining country.

The leading petrographical features of the Lower Silurian strata are their frequent sharp alternate anticlinal and synclinal undulations; their strike, which varies in bearing from magnetic north to north-west, and the invariably high rate of easterly or westerly incline of the bands at angles of from 60° to vertical. Lithologically, sandstones, slates, shales, and mudstones constitute the prevailing types, and of these there are many varieties and blendings of character. The sandstones vary from hard, dense quartzose, and gritty, fine and coarse to soft and argillaceous, the latter being usually more or less micaceous. They occur in bands of from less than an inch to many feet in thickness, sometimes distinctly schistose and sometimes exhibiting little or no lamination. At the surface their prevailing colours are different shades of brown, grey, and sometimes yellow, reddish, or nearly white; but below water-level they are dark-grey or blue, sometimes nearly black, and occasionally of a dark-greenish colour. Bands of hard, dense quartzite or quartz-rock, as distinguished from vein quartz, are frequent in the Whipstick country, north-west from Sandhurst, and also, more rarely, in other localities. Conglomerates and breccias are very rare. A slate conglomerate is noted on one of the geological maps as occurring at Spring Plains, and a quartzite breccia is described by Professor Ulrich as occurring near Maldon.

The slates, shales, and mudstones exhibit as many degrees of texture, hardness, and colour as the sandstones. At the surface

they are usually white, grey, brown, yellow, or reddish, occasionally mottled, and sometimes dark-grey or blue. Like the sandstones, they are almost invariably dark-coloured below the water-level. The cleavage and the stratification of the argillaceous layers are generally identical, but cleavage distinct from stratification is not uncommon.

No limestone bands have yet been found among the rocks of the Lower Silurian series in the area west of Melbourne.

The characteristic and most abundant fossils of these rocks are graptolites (*polyzoa*), on the evidence of which Professor McCoy was enabled to co-relate the Victorian Lower Silurian strata with those of Europe and America.

In the commencement of the first decade of his Prodromus of the Palæontology of Victoria, Professor McCoy mentions that, shortly before coming to Victoria, he found in the slate-rocks of the old Roman gold-mines in Wales exactly the same species of graptolites as those which he subsequently discovered to be the most common in the gold-field slates of this colony; and that the Romans had in Wales obtained gold from quartz-veins traversing slates of exactly the same geological age as those of Victoria.

The series known as the Llandeilo flags and the Bala rocks in Wales are those to which our Lower Silurian rocks are shown on palæontological evidence to be the equivalents. The various species of the family Graptolitidæ which have been found in Victoria, and have been figured and described by Professor McCoy in his decades, are as follows:—

Phyllograptus folium (His. sp.), var. ***typus*** (Hall); ***Diplograpsus mucronatus*** (Hall sp.); ***D. pristis*** (His. sp.); ***D. rectangularis*** (McCoy); ***D. bicornis*** (Hall); ***Didymograpsus fruticosus*** (Hall sp.); ***D. quadribrachiatus*** (Hall sp.); ***D. bryonides*** (Hall sp.); ***D. octobrachiatus*** (Hall sp.); ***D. Logani*** (Hall) var. ***Australis*** (McCoy); ***D. extensus*** (Hall); ***D. caduceus*** (Salter); ***Diplograpsus palmeus*** (Barr sp.); ***Cladograpsus ramosus*** (Hall sp.); ***C. furcatus*** (Hall sp.); ***Didymograpsus gracilis; D. Thureaui*** (McCoy); ***D. Headi*** (Hall). The only forms other than graptolites, mentioned by Mr. A. R. C. Selwyn in his essay, are ***Hymenocaris, Siphontreta*** (***S. micula,*** McCoy), and ***Lingula.***

The Silurian rocks occurring eastward of a line from the Macalister River in Gippsland to near Benalla, have been provisionally referred to the Lower Silurian groups, partly on account of their lithological resemblance to those westward of Melbourne, and partly because of the discovery in the slates at Deddick, near the New South Wales boundary line, of a graptolite (***Diplograpsus rectangularis,*** McCoy), and the identification at Guttamurrh Creek, Snowy River, of ***Didymograpsus caduceus*** and ***Diplograpsus foliaceus*** in vertical slates capping the granite.

It is very likely, however, that the classification of the rocks of a considerable area in the eastern part of the colony may have to be altered from Lower to Upper Silurian, if further investigation tends to corroborate some slight evidence already obtained in that direction.

The ranges consisting of Lower Silurian rocks in the western portion of Victoria nowhere greatly exceeded 2,000 feet in altitude, and are generally much lower. The axial line of the Main Divide is nearly at right angles to the strike of the rock layers, while the courses of the principal rivers and creeks, and of the leading spurs separating them, approximately conform to the latter in general direction. Portion of the eastern (presumably Lower) Silurian area is more alpine in its character; the two highest mountains, Mounts Hotham and Feathertop, exceed 6,000 feet in height, and the features of the country are on a grander scale than in the western area, where the character of the Lower Silurian ranges is marked by a general sameness.

Upper Silurian Rocks.

As before stated, the provedly Upper Silurian rocks occupy the central portion of the main mountain system of Victoria, within an area of about 100 miles in width, bounded on the west by a line from Melbourne to Heathcote, and on the east by the Macalister River and a line thence to Benalla.

The northernmost extension of the rocks of this area is where they slope beneath the Murray Tertiaries, at the extremity of the Mount Camel Range; and their southernmost exposure, separated by an area of superimposed Mesozoic rocks from the spurs of the Main Divide, but without doubt continuous with the latter under the Mesozoic rocks, is within a tract bordering the coast of Waratah Bay and Corner Inlet, from Cape Liptrap to the Bennison River, near Foster. About 10 miles north of Foster a small outcrop of Upper Silurian rocks through the Mesozoic strata occurs at Turton's Creek.

Mr. A. R. C. Selwyn remarks, in his work, that "a considerable unconformity certainly exists between the Upper and Lower Silurian groups; they present differences in general lithological character and physical structure similar to those observed between the same groups in Britain."

I conceive, however, that the unconformity here remarked by Mr. Selwyn simply refers to their lithological character, as the precise lines of junction of the two groups have not been so nearly ascertained as to enable it to be stated that they are stratigraphically unconformable.

The undulations of the Upper Silurian rocks appear to be less frequent than those of the Lower; the average rate of dip is also less in the former, the general rate being from 45° to 80°, though

vertical bands are not uncommon. The general strike of the Upper Silurian strata is from N.N.W. to N.W., though at Cape Liptrap and Turton's Creek it takes the abnormal direction of from N. 10° E. to N. 30° E. Considerable contortion is also observable in the rocks along the Cape Liptrap coast. (See Figs. 6 and 7.)

FIG. 6.—SECTION.

These rocks exhibit as many varieties of texture, colour, and hardness as do those of the Lower Silurian group, but are usually less slaty than the latter. They consist principally of sandstones, mudstones, rubbly shales, and, occasionally, slates or schists. Breccias, conglomerates, and quartzites are sometimes met with, as at Heathcote, Anderson's Creek, the Alexandra district, Cape Liptrap, and other localities. At Cape Liptrap and Turton's Creek are bands composed of a curious mixture of volcanic and calcareous sedimentary ingredients. Limestones of very excellent quality occur at Lillydale, at Waratah Bay, east from Cape Liptrap, and near the Tyers River in Gippsland. Bands of nearly white, somewhat slaty, saccharoidal marble and grey sub-crystalline limestones occur among what are supposed to be Upper, but may be Lower, Silurian rocks in the Limestone River, one of the heads of the Murray; and in the heads of the Buchan River, on the south side of the Main Divide, is an outcrop from beneath the Snowy River porphyries of the previously mentioned acutely corrugated metamorphic calcareous schist, the geographical position of which is also doubtful.

FIG. 7.—PLAN.

Steep Silurian banks.

Further north, however, on the Gibbo River, is a similar limestone, in which Mr. A. W. Howitt found a fossil, identified by Professor McCoy as *Palæopora,* indicative of Upper Silurian. Other more or less calcareous bands are not unfrequent.

Several masses of encrinital limestone, or marble, occur in the valley of the Thomson River in Gippsland, and one near the Delatite River, 5 miles westerly from Mansfield. A striking similarity of lithological character exists between all of these, and, though far apart, they are in the same belt of rock-bands. The limestone is grey to dark bluish-grey, compact to crystalline, and full of crinoid stems replaced by carbonate of lime. On being

polished, the limestone base is nearly black, while the fossil markings are white, giving the stone a somewhat ornamental appearance.

Among some very imperfect fossils collected from one of these patches at Cooper's Creek, near the Thomson River copper-mine, Professor McCoy was enabled to identify *Favosites Goldfussi* with traces of a lamelliferous coral closely allied to *Diplophyllum cæspitosum*, small branching forms allied to *Trematopora astiolata* and *Cladopora fibrosa*, and one *Beyrichia* allied to *B. lata*, with crinoid stems of the *Actinocrinus* type.

From another patch on the south side of the Thomson River, between Walhalla and Toongabbie, were obtained numerous crinoid stems of the *Actinocrinus* type, some traces of *Gasteropoda* apparently of the genus *Acroculia*, but too imperfect for determination, and a fragment of *Bellerophon*.

From a third patch on the banks of the Deep Creek, a branch of the Thomson, were obtained only indeterminable fragments of crinoid stems and the coral allied to *Trematopora astiolata* found in the Cooper's Creek limestone.

This imperfect palæontological evidence was, in Professor McCoy's opinion, closely indicative of Upper Silurian, though at one time there appeared grounds for believing that the various limestone patches referred to—clearly identical with one another in geological position—might be Devonian, as they appear at first sight to fill deep hollows or pockets in the ordinary Silurian rocks, and to be the vestiges of what were once more extensively developed beds of more recent date. On further examination, however, it was found that they are in reality portions of lenticular shaped beds of limestone, of limited extent, intercalated with the ordinary Upper Silurian rocks. When the Upper Silurian rocks were in process of deposition as sediments, isolated colonies of various forms of marine life appear to have occupied portions of the sea-bed; these extracted lime from the sea water, and by their action beds of limestone were formed over limited areas, while around them the ordinary deposits of silt, &c., were being accumulated. They were subsequently covered, indurated, and folded with the rest of the Silurian rocks, and here and there have been laid bare by denudation, so that they present the appearance of wedge-shaped vertical masses of limestone fitting into corresponding "pockets" in the slates.

In one well-marked instance, near the Thomson River, between Toongabbie and Walhalla, a quarry has been opened in the encrinital limestone, or marble, on the brow of a steep hill; downward the limestone disappears, and nothing but slates and shales can be seen along the face of exposed rock below the quarry. In the bed of the creek at the bottom of the hill, and in the same line of strike with the large limestone mass above, is a small

isolated vertical lenticular mass of limestone of the same character, about a couple of feet long and one foot thick, thinning out to nothing upwards and downwards, and entirely enclosed by the slates except on the exposed face. The proof here as to the limestone being an intercalated deposit, and of the same age as the associated Upper Silurian slates, is beyond question.

On palæontological evidence the Upper Silurian rocks of Victoria have been identified as the equivalents of the Wenlock shales, May Hill sandstones, and Upper Ludlow rocks of England, by Professor McCoy, who has figured and described in his decades the following named fossils :—

Petraster Smithii (McCoy) ; *Urastella Selwyni* (McCoy) ; A Graptolite—*Retiolites Australis* (McCoy) ; Trilobites—*Phacops caudatus* (Brong) ; *P. fecundus* (Bar.) ; *Forbesia euryceps* (McCoy); *Lichas Australis* (McCoy); and *Homalonotus Harrisoni* (McCoy); *Leptæna* (*Leptagonia*) *rhomboidalis* (Wilck. sp.); *Trematospira liopleura* (McCoy); *T. formosa* (Hall); *Spirifera plicatella* (Lin.), var. *macropleura* (Conrad) ; *S. sulcata* (His.) ; *Sprigerina reticularis* (Lin. sp.) ; *Rhynchonella* (*hemithyris*) *decemplicata* (Sow.); *Nucleospira Australis* (McCoy); *Pentamerus Australis* (McCoy); *Cardium Gippslandicum* (McCoy); *Orthoceras* (*cycloceras*) *Ibex* (Sow.); *O. bullatum* (Sow.); *O. capillosum* (Bar.); *O. Lineare* (Munst.); *O. Striato-punctatum* (Munst.).

The general character of the Upper Silurian country is very mountainous, though a great deal of it, especially around Melbourne, is only moderately hilly or slightly undulating.

The crest of the Main Divide, from Mount Arnold to the heads of the Barkly, a western branch of the Macalister, maintains an average elevation of over 4,000 feet, and consists, as do most of the branch range systems on either side, entirely of Upper Silurian rocks. The descents from the Main Divide and its leading spurs into the creeks and rivers are very abrupt, and sometimes precipitous ; a very dense and luxuriant vegetation, consisting of large Eucalypts, the various scrubs, and tree ferns, is found wherever the depth of surface soil and rubble and the climatic conditions are favorable, especially on the south side of the Main Divide, in the heads of the Yarra, the La Trobe, the Tanjil, and the Thomson Rivers.

CHAPTER V.

Middle and Upper Palæozoic Rocks. Snowy River Porphyries—character and origin; scenery. Middle Devonian Rocks—limestones, fossils; Bindi and Buchan limestones; igneous beds of the Buchan group; Mr. A. W. Howitt's remarks; character of Devonian limestone country. The Tabberabbera Middle Devonian Rocks. Upper Palæozoic Rocks. The Grampian Sandstones. The Avon and Macalister Rocks; the Mansfield beds; the Mount Tambo beds. Conglomerate of Wild-duck Creek.

MIDDLE AND UPPER PALÆOZOIC ROCKS.

In this group are included—(1) Certain igneous rocks occurring in Gippsland, and known as the Snowy River porphyries; (2) Limestone and other rocks occurring in various localities, and shown on palæontological evidence to be of Middle Devonian age; (3) A series of conglomerates, sandstones, shales, and contemporaneous trappean rocks, some of which can be referred to the Upper Devonian period, and others, though also provisionally classed as such, may be of later date.

In describing these three groups of rock, I avail myself largely of the information given by Mr. A. W. Howitt, in his contributions to the Geological Progress Reports (No. III., pages 189 to 249, and No. V., pages 117 to 129), and simply give a general synopsis of that gentleman's observations and conclusions, though I have had the pleasure of personally examining, in his company, much of the country described.

The Snowy River porphyries constitute a belt which passes into Victoria from New South Wales, and occupies at the boundary line a breadth of nearly 20 miles, extending between the head of the Murray, near Forest Hill, and a little to the east of the Snowy River. The western boundary of the belt includes the Cobberas, and runs south to near the head of Lake Tyers. The eastern boundary runs southward, keeping parallel with, and slightly eastward of, the Snowy River; and the porphyries constituting the belt extend down to and disappear under the Tertiary deposits which border the coast on either side of the Snowy River mouth.

The rocks to the east and west of the belt consist of granite, "regional," metamorphic schists, and Silurian rocks. The main portion of the belt forms a mountainous plateau, lying between the Snowy River and its western tributary, the Buchan; and this plateau has a general slope, from an elevation of from 4,000 to 6,000 feet, near the Cobberas, to a level of about 1,000 feet above the sea, near the margin of the marine Tertiaries under which the porphyries disappear near the coast line.

This general slope is not merely due to denudation—though that agency has exercised upon it a certain modifying effect, and has also produced great surface changes in eroding valleys, &c.—but chiefly to an actual dip in the ancient land surface of the period to which the porphyries belong, as it is found that the Lower Palæozoic rock-foundation on which they rest has a similar slope; and that, while at the northern portion of the plateau the Lower Palæozoic rocks constitute from 2,000 to 2,500 feet of its base, and the porphyries form the remainder, the former pass out of sight beneath the level of the rivers near Buchan, where the latter still reach an altitude of 2,000 feet above the sea.

The bulk of the rocks consists of felstone-porphyries, felstone-ash, and agglomerates; the lower portions of the series approach more nearly to the quartz-porphyries in character, and are more compact and porphyritic than the upper 2,000 feet, which exhibit clearly a fragmentary character. The fragmentary portions vary from microscopic dust to several feet in diameter, are usually angular, more rarely slightly rounded, and consists of felstones and quartz-porphyries of various kinds embedded in a felstone base. The occurrence of a fragment of well-marked granite among the varieties of felstones and quartz-porphyries is also noted by Mr. Howitt, who adds, however, that he has not observed fragments of sedimentary rocks in these agglomerates. In places, particularly in the Little River, a branch of the Snowy River, a distinct bedded or stratified appearance is noticeable both in the fragmentary and in the more compact and porphyritic felstones, though they do not present any evidence of the action of water in sorting and arranging the beds. (Figs. 8 and 9.)

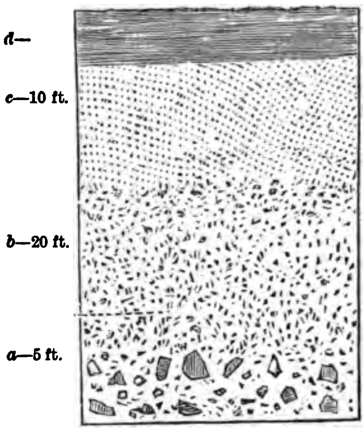
FIG. 8.—LITTLE RIVER.

Dip of beds, N. 15°.

Some of the higher mountains rising from the general level of the table-land are marked by central masses of quartz-porphyry of a distinctive character from the bulk of the Snowy River porphyries.

In the north, the Cobberas, the Wombargo Mountain, and the range thence northward to Mount Hotham, and in the south, Mount Tara and Mount Nowa Nowa belong to this class. The general conclusions arrived at by Mr. Howitt are, to quote his own

FIG. 9.—NEAR MURRINDAL RIVER.



(*d*) Very fine-grained rock—felspathic; dark to light purple, in alternating bands of colour. Throughout the fine-grained rock there are patches of coarse particles. The dip is probably N. 10°-20° E. at 53°.

(*c*) Similar fine-grained rock, with coarse fragments imbedded.

(*b*) Fine-grained rock, grey in colour; under the lens particles can be made out which are angular—some seem to be minute prisms of felspar.

(*a*) Agglomerate of varieties of felstones, from 12 inches diameter to dust. The surface weathers very rough.

words, that—"The Snowy River porphyries may be regarded as a great volcanic sheet, the lowest part of which is seen in the Little River and the upper part at the Wombargo uplands. It rests upon the Lower Palæozoic foundation, and in places has been let down by faults into it. Its lowest portions approach the quartz-porphyries in character, and in ascending it becomes more and more fragmentary."

In a portion of the district "these great masses of felspathic rocks seem to lie grouped around a central mass of quartz-porphyries of a somewhat peculiar character." Mr. Howitt proceeds to draw "the inference that in the Snowy River porphyries we may see the accumulations of ash, agglomerates, and lavas, due to former volcanic activity in Palæozoic times," and that "these rocks, whose characters are obscure, may well be regarded as having undergone such changes that former beds of fine ash, or even of agglomerates, may have become structureless rock-masses of siliceous and felsitic character."

The ridge extending from the Cobberas to near Buchan, along which occur the masses of quartz-porphyries, is regarded by Mr. Howitt as indicating the line of "a meridional fissure on which a series of volcanoes was built up," and the masses of quartz-porphyry as the "denuded stumps of volcanoes round which

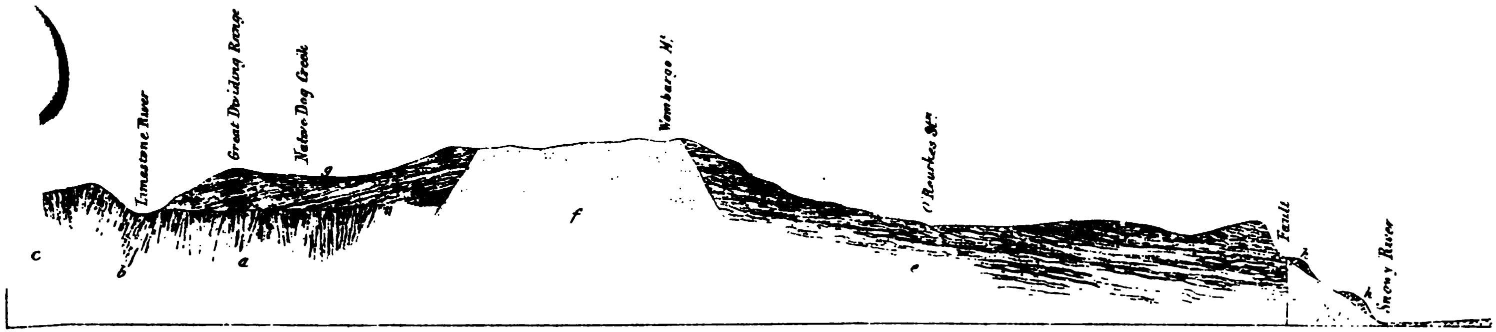


Fig. No. 10.—SKETCH SECTION ACROSS THE WOMBARGO MOUNTAIN, FROM THE LIMESTONE RIVER TO THE SNOWY RIVER.

*Scale.—**Horizontal**, One Inch to 4 **Miles**; Vertical, One Inch to 4,000 feet.*

*(a) **Silurian**; (b) **Limestones**; (c) **Mica** schist and **gneiss**; (d) Granites; (e) **Snowy River** Porphyries; (f) **Quartz Porphyries**; (g) **Devonian Limestones**; (h) Tertiary **Basalts***

FIG. No. 11.—GORGE OF THE LITTLE RIVER.

accumulations of felstone, ash, and agglomerate, with felsitic rocks of indefinite character are still to be seen grouped." (Fig. 10.)

From the fact of their being clearly more recent than the Silurian rocks, and from their being overlaid in places by the Middle Devonian limestones, the Snowy River porphyries may with tolerable certainty be referred to the Lower, or to the lower portion of the Middle, Devonian period, the limestones of which latter epoch will next be noticed.

It may also be safely inferred that these Devonian lava-flows filled, or partly filled, a great trough in the Lower Palæozoic strata and granites, and that the sides of that trough rose to a far greater elevation than they reach now. The action of denudation has had less effect on the porphyries than on their boundary rocks, and has reduced the latter to a lower level than the former. Some idea of the extent of this denuding action will be conveyed in the remarks on the Upper Devonian rocks.

The soil yielded by the Snowy River porphyries is usually poor and gritty, though in the flat valleys near the heads of the streams there is a black peaty soil, supporting a fair growth of snow-grass and sub-alpine plants. The timber and scrubs are, as a rule, inferior and scanty. The scenery generally, however, is by no means devoid of attractiveness. The loftier summits are characterized by a stern, rugged grandeur, while the lower portions of some of the creeks and rivers wind through precipitous ravines and canõns, forming successions of picturesque waterfalls and deep pools. (Fig. 11.)

One of the grandest views of mountain scenery, and at the same time one of the finest examples of the results of denudation to be found in Victoria, is to be seen from Turn-back Mountain, overlooking the great valley of the Snowy River.

Middle Devonian Rocks.

Bindi and Buchan Limestones, &c.

These rocks appear to be confined to the eastern half of the colony, and only occur at wide intervals as isolated patches of from several square miles to a few acres in extent, occupying hollows in older rocks. The largest areas of the typical limestones of this series are at Bindi, on the Tambo River, and at Buchan, at the junction of the Buchan and Murrindal Rivers.

The fossils found in these limestones are described by Professor McCoy as characteristic of the Middle Devonian epoch, and some of them are perfectly identical with some found in the European Middle Devonian limestones of the Eifel.

The fossils described and figured by Professor McCoy in his decades are as follows :—*Favosites Goldfussi* (d'Orb.), a coral; *Spirifera lævicostata* (Val.), *Chonetes Australis* (McCoy), and *Phragmoceras subtrigonum* (McCoy), Molluscs; *Asterolepis ornata*

(Eichwald), var. *Australis* (McCoy), a ganoid placodermatous fish, concerning which Professor McCoy remarks that it is an extraordinary circumstance to find in Australia these representatives of the "great ganoid armour-plated fishes" of the genus *Asterolepis*, which are amongst the most abundant and striking characteristics of the Devonian rocks of Russia, "in limestones of the same age, and accompanied by the corals and shells of the Plymouth and Eifel limestones of similar age, with which they are not known to occur in England or Germany, and which do not occur with them in the Russian beds."

The Bindi limestones constitute a patch low down in the valley, and on the east side of the Tambo River, and occupy a basin in the older rocks, which here consist of granites, quartz-porphyries, and indurated Silurian slates. The Tambo River has eroded its course round the northern and western margins of the limestones, along their junction with the older rocks, and consequently a large portion of the western side of the limestone area has been removed.

The dip of the limestone beds which remain is to the southwest, or from their eastern rim.

The fossils found in the Bindi limestones are principally the characteristic spirifers, and are very plentiful.

The Buchan limestones occur between the Buchan and Murrindal Rivers, near their junction, and occupy a deep hollow in the Snowy River porphyries, into which they have been further let down by faults. The limestones are dark-blue to nearly black, compact, and somewhat thickly bedded, and generally dip away from the porphyries which encircle them. They also show evidences of having been subjected to considerable folding and contortion in places. Numerous sink-holes occur in this limestone tract; in one place the Murrindal River flows into a sink-hole, and has for some distance a subterranean passage, re-appearing again further down its course. A surface channel exists, but water only flows in it during floods, when the quantity is too great to escape by the underground passage.

All the above-mentioned fossils have been found in the Buchan limestones.

Other similar but smaller patches of Middle Devonian limestone occur—occupying hollows in the Snowy River porphyries—in the valley of Basin Creek, eastward from the Murrindal; in the Yalong Creek, near its junction with the Snowy River; at Gellingall, at the junction of the Woolshed Creek and the Buchan; at the junction of the Snowy River and the Buchan; and at Butcher's Ridges, near Gelantipy, where there are three patches occupying hollows in the porphyries—one capped by basalt on the table-land, and two other smaller ones on either side of Butcher's Creek.

All these patches and outliers are similar in lithological character to the typical limestones of Buchan, and contain the characteristic Middle Devonian spirifers found in the latter.

The above-described marine limestones, whose total thickness is estimated at 400 or 500 feet only, form the upper portion of the Middle Devonian group, which they serve to identify. The base of the group is composed of rocks of a different character, which are found underlying the limestones and intervening between them and the (Lower Devonian) Snowy River porphyries.

This subject has been ably worked out by Mr. A. W. Howitt, from whose notes on the Devonian rocks of North Gippsland, published in the Geological Progress Report, No. V., pages 117 and following, I extract the following leading observations :—

The lower beds of the Buchan group exhibit a thickness of from 700 to 1,000 feet of calcareous tufas, felsite tufas, breccias, &c., between which and the Snowy River porphyries certain well-marked distinctions are noticeable. As previously shown in describing the latter, no traces of aqueous action in their arrangement can be observed, and the volcanic materials which compose them appear to have fallen, and to have been arranged, on land ; whereas, from the base of the Buchan series and upwards to the unmistakably marine limestones, the tufas, breccias, &c., are of a character which clearly indicates that their component volcanic and other materials fell into, and were arranged by, water. From the partculars given by Mr. Howitt in a number of sections, the lowest beds consist of unstratified breccia-conglomerates, composed of rounded and angular felsite blocks, with fragments of slates and sandstones resembling those of the Lower Palæozoic formations.

Above these occur fine and coarse breccia-conglomerates made up of similar fragments and sandstones composed of felsitic grains, all showing to a greater or less extent distinct signs of bedding.

A sheet of compact felsite and one of basalt, apparently representing lava-flows, are shown as occurring above these in one section given by Mr. Howitt.

On thick red beds, resembling sandstones, rest the lowest limestones, above which occur thick yellow beds, apparently either decomposed felsites or consolidated felsitic mud. These are followed by thin-bedded limestones, some of which contain numerous angular felsite fragments, deposited either irregularly or in bands ; above these lie the thicker bedded compact blue limestones. The following are verbatim quotations from Mr. Howitt's treatise :—

" The Buchan limestones are therefore only part of a continuous series. The lower part of the group consists of coarsely aggregated felsitic breccias, the coarseness of material decreasing, but with alternations of texture, in ascending. The deposits also become more distinctly bedded, and in places, as at Butcher's Creek, pass into or alternate with subordinate conglomerates in which angular or rounded fragments of sedimentary rocks are of common

occurrence. In all the late and in many of the earlier beds, aqueous arrangement is clearly distinguishable. The coarse angular breccias at the base indicate, I think, a shore line.

"In all the sections occur felsitic sheets which, as a rule, are compact, and are found under conditions which almost always suggest that they are of contemporaneous origin.

"The passage beds are compounds in varying percentages of limestones and felsitic particles, the latter varying in dimensions from mere dust to several inches in diameter.

"The felsitic admixture gradually, or in places, suddenly ceases, and the remaining beds of the group are then purely limestones of the ordinary character seen at Buchan, and characterized by a numerous marine fauna of Devonian age.

* * * * * "The general conditions indicated are, I think, these:—1. A sinking coast-line with either marine or littoral volcanoes, from which trachytic materials were ejected as fragments, or emitted as flows of lava (felsite-breccias, tufas, compact, and porphyritic felsites).

"2. Gradual extinction of volcanic activity as indicated by the finer character of the felsite fragments, their intermixture with calcareous materials (calcareous felsite-tufas) and their final cessation with succession of purely marine limestones."

Two small outliers occupy respectively small basins at Cowombat, on the fall towards the Murray, in the north-eastern corner of the colony, near Forest Hill, and at the sources of the Native Dog Creek, the head of the Buchan, on the southern slope of the Main Divide. In the first of these outliers, the observable strata consist of nearly vertical yellowish and blue thin shales, with some bands of calcareous shale and limestone, resting on the Snowy River (Lower Devonian) porphyries and altered Silurian rocks. In the second outlier, the rocks consist of dark shales, with calcareous nodules, and blue compact limestones, also resting on the Snowy River porphyries. The elevations of these outliers above the sea probably exceed 3,000 feet.

In both places imperfect fossils (corals and small brachiopods) have been found, which Professor McCoy considered to be indicative of Middle Devonian age, though probably younger than the Bindi and Buchan limestones.

A patch of Middle Devonian limestone is indicated on the Geological Sketch-map as occurring to the east of the Mitta Mitta River, south from Mount Gibbo, but has not been sufficiently examined to admit of details being given.

The tracts occupied by the Middle Devonian limestones are smoothly rounded and hilly, or undulating, with occasional cliffs and scaurs; the soil is of fair quality, well grassed, and supports a medium but thinly-scattered growth of timber. The general aspect of the country is park-like, and affords a pleasing contrast to the rugged sterile appearance of the encircling mountains.

THE TABBERABBERA SHALES AND COBANNAH QUARTZITES.

Another group of rocks of Middle Devonian age was found by Mr. A. W. Howitt to occur at Tabberabbera, at the junction of the Mitchell and Wentworth Rivers, where, in black shales, associated with limestones, he found the characteristic *Spirifera lævicostata* of the Buchan and Bindi limestones. Besides the black shale and limestones, there is a series of slates, flinty shales, sandstones, and quartzites, apparently belonging to the same group, extending south-westward from Tabberabbera beyond Cobannah, and over to Maximilian Creek, a branch of the Freestone Creek, running into the Avon River.

These rocks have been folded, compressed, indurated, and metamorphosed, and so nearly resemble somewhat altered Silurian strata that, prior to Mr. Howitt's investigations, they were classed as such. They are, however, according to notes furnished me by Mr. Howitt, unconformable, and their folding has been effected subsequently to that of the Silurian rocks. On the north and east these rocks appear to be bounded by granite and Silurian rocks, while on the south and west they pass under the Upper Devonian rocks of the Iguana Creek and Maximilian Creek.

With the Middle Devonian rocks we lose the more conspicuous indications of metamorphism, contortion, and folding which form such prominent characteristics of the Lower Palæozoic and of the last described group of the Devonian rocks.

The rock-bands in the newer formations, including that to be described next in order as Upper Palæozoic, though generally uptilted and undulating, are in some cases horizontal, and have nowhere been folded or metamorphosed to the extent observable in the older rocks.

The Tabberabbera and Cobannah rocks may with tolerable safety be regarded as Middle Devonian ; they are certainly not of more recent date, and, as above stated, show an amount of undulation in their beds equal to that observed in the Silurian rocks, but are unconformable to the latter, while the Upper Devonian rocks of Iguana Creek, which immediately overlie them, rest almost horizontally on their upturned and denuded edges, showing that, notwithstanding the close geological relation between the Middle and Upper Devonian Groups, a very conspicuous stratigraphical unconformity exists between the two.

In fact, the observed stratigraphical relations to one another of the various groups of Palæozoic rocks naturally suggest their classification in three main divisions—(1) Lower Palæozoic, including Lower and Upper Silurian ; (2) Middle Palæozoic, comprising the Lower and Middle Devonian ; and (3) Upper Palæozoic, including the whole series of the Upper Devonian rocks and those provisionally classed under the general term of Upper Palæozoic.

UPPER PALÆOZOIC.

Under the above provisional heading are here included the Upper Devonian rocks proper, and also the rocks of two large and several small areas occurring at wide distances apart throughout the colony. In some cases, stratigraphical position and lithological character constitute the only grounds on which the classification is based; in others the fossil flora indicate a range from Middle Devonian to Lower Carboniferous.

The Grampian Sandstones, in the western portion of the colony, constitute one of the two large Upper Palæozoic areas; the other is situated partly in North Gippsland, and appears to extend over the Main Divide to Mansfield.

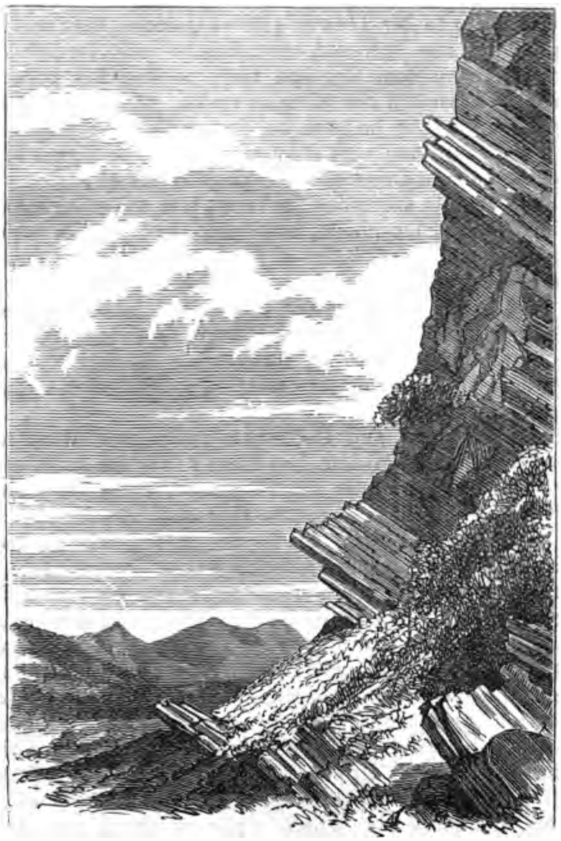


FIG. 12.—LEDCOURT QUARRY, Grampians (looking South). Dip of sandstone beds W. 28°, S. 33° 30′.

Commencing with the western area, we find the ranges of the Grampians composed of a group of sandstones which rest partly on granite and trappean rocks, and partly on metamorphic and Lower Silurian strata.

As no further scientific examination has been made of the Grampian Sandstones since the publication of Mr. A. R. C. Selwyn's work in 1866, I cannot do better than quote that gentleman's observations:—

* * "A thickness of upwards of 2,000 feet is exposed in the precipitous escarpments of the Grampians, Mount Sturgeon, Mount Abrupt, and the eastern face of the Victoria Ranges. The lithological character of the series, as exhibited in the Grampians, is strictly arenaceous—massive thick-bedded sandstones, with bands of sandy flags, but no slaty or shaly beds. Considerable varieties occur in texture and composition, from very hard siliceous grit and quartz rock, with included pebbles of white quartz (as at Mount Talbot, Mount Arapiles, and the Black Range), to hard and soft fine-grained freestones. The prevailing colours are shades of whitish-brown, reddish-brown, and white, and rarely brick-red. Much cross-stratification or false bedding is observable, but the whole formation has a westerly dip at rather low angles, giving a gentle slope to the face of the hills in that direction, whilst to the eastward the beds terminate abruptly in bold rocky escarpments and almost vertical cliffs several hundred feet in height. (Fig. 12.)

"In the Dundas and Black Ranges, the dip of the beds is reversed or to the eastward, indicating a synclinal axis between these hills and the Grampians, Sierra, and Victorian Ranges.

"In some places the beds are seen to rest directly on granite, whilst in others they rest on the up-turned and denuded edges of the Silurian strata."

During a very brief visit to that portion of the country, I found that the rocks of the Dundas Range form an isolated patch of the same character as, and evidently once continuous with, the rocks to the eastward.

The intermediate portions have been removed by denudation, and the subjacent metamorphic rocks have been laid bare on the western side of a broad valley, occupied principally by Tertiary deposits, which extends from Cavendish to the Glenelg, and separates the Dundas from the Sierra and Victoria Ranges.

To the north, Mount Arapiles, and several smaller hills composed of the same rocks, form tolerably lofty isolated outcrops,

rising abruptly from the level Tertiary country which surrounds them; and it appears likely that the Upper Palæozoic rocks may underlie a large extent of the Tertiary tract to the north-west.

The general physical features of the ranges indicate, beyond a doubt, that the Upper Palæozoic rocks which compose them are but vestiges of a once more extensively developed formation, and that to long-continued powerful denuding action is due the removal of the major portion of the series.

The eastern Upper Palæozoic area has only been examined at its northern and southern portions, near Mansfield, and in Gippsland, respectively. There appears little doubt as to the rocks of the series extending continuously between the two localities and constituting a portion of the Main Divide, of which a proper geological examination has not yet been made. Viewed as a whole, this area is in the form of a wide strip or belt of about 100 miles in length, north-west and south-east, and averaging 20 miles in width. The general south-western boundaries of this Upper Palæozoic tract are the Macalister River, and its western tributary, the Barkly River, on the southern or Gippsland fall of the Main Divide, and a line crossing obliquely the upper portions and including the heads of the Jamieson, Howqua, and Delatite Rivers, eastern tributaries of the Goulburn, on the northern slope towards the Murray. The north-western and northern boundary is formed by the steep Silurian and granite spurs of the Strathbogie Ranges, and the Blue Range, near Barjarg. The north-eastern limit on the fall towards the Murray is approximately a line from the Blue Range between the Broken River and the King River, to near the head of the latter at the Main Divide, and thence on the Gippsland side, a line to the west of, and roughly parallel with, the Wonnongatta or Mitchell River to Maximilian Creek, where the boundary line turns eastward and then northward to Tabberabbera. The rocks of the belt here extend eastward of the Mitchell, and occupy portion of the country on that side from Tabberabbera to near Bairnsdale. The southern boundary is formed by the low-lying Tertiary deposits which flank the Upper Palæozoic rocks along an irregular line from the Macalister River at Glenmaggie to the Mitchell River at Iguana Creek.

The Iguana Creek beds are the typical rocks of that group of the Upper Palæozoic division, which has been classed, on good evidence, as Upper Devonian, and they are comprised in that portion of the great Upper Palæozoic area which extends eastward from Freestone Creek, a branch of the Avon River. The northern boundary of this particular portion is a line skirting Maximilian

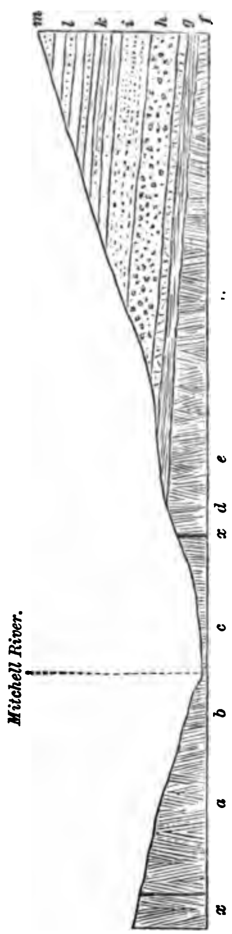
Creek, the eastern branch of the Freestone, winding thence round the south of Yellowman's Nob, on the Crooked River road, and thence northward to Tabberabbera at the junction of the Mitchell and Wentworth Rivers.

The southern boundary is, as before stated, formed by the flanking Tertiary deposits as far as Iguana Creek. The Mitchell River itself flows approximately along the line of junction of the Tertiariesand the Upper Palæozoic rocks,forming the south-western boundary of the latter from Iguana Creek to near Bairnsdale, whence their north-eastern margin or line of contact with the Silurian rocks runs north-westerly to Tabberabbera. From near Tabberabbera to Iguana Creek, the Mitchell runs between cliffs of the rocks of the Iguana Creeks groups.

Outside the eastern margin of the main mass, Mount Taylor, whose base consists of porphyritic granites, and several other hills, are capped with outliers of these Upper Devonian rocks. The term "Iguana Creek beds" was adopted, and the reference of the rocks to the Upper Devonian period determined, because characteristic fossil plant-impressions were found in the shales intercalated with the sandstones and conglomerates, which form lofty cliffs on either side of Iguana Creek, above its junction with the Mitchell. The fossil plant-impressions from here which have been determined, figured, and described by Professor McCoy, are as follows :—*Cordaites Australis* (McCoy), *Archæopteris Howitti* (McCoy)—allied to the Canadian Upper Devonian, *A. Jacksoni*, and to the *A. Hibernica* of the Upper Devonian of Kilkenny and Berwickshire, and *Sphenopteris* (*Eremopteris*) *Iguanensis* (McCoy), somewhat differing from, but apparently most nearly allied to, the *Sphenopteris Artemesifolia* of the Lower Carboniferous rocks of Northumberland.

In an interesting account of a canoe voyage down the Mitchell from Tabberabbera (Geological Progress Report, No. III., page 214 and following), Mr. A. W. Howitt describes the nearly vertical Middle Devonian rocks, exposed in the river gorge, as being overlaid by very slightly dipping Upper Devonian beds of the Iguana Creek group, which, as the river is followed down, gradually slope down to its bed, the older rocks passing out of sight beneath. The lowest beds of the Upper Devonian group, observed here, appear to be bedded felstones, over which lie conglomerates and sandstones, fine and coarse siliceous conglomerates, quartzose sandstones, with pebble bands, gritty flags, and reddish sandstones. (Fig. 13.)

Fig. 13.—Sketch Section, Tabberabbera.



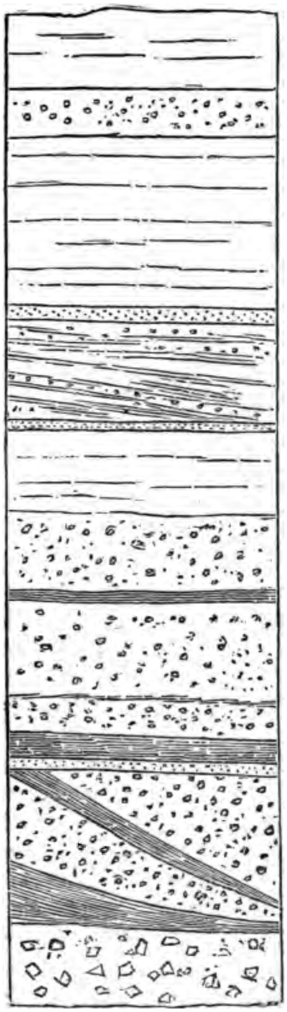
Scale:—Horizontal, 20 chains = 1 inch; vertical, 1,000 feet = 1 inch.

Iguana Creek Beds.
- (*l*) Pale-coloured sandstone.
- (*k*) Reddish sandstone.
- (*i*) White siliceous grit.
- (*h*) Quartz conglomerate.
- (*g*) Quartziferous and geodic felstone.
- (*f*) Dark-red unstratified argillaceous rock.

Tabberabbera Shales.
- (*e*) Thin slates, passing to the eastward through yellow shales into highly indurated and altered rocks.
- (*d*) Fossiliferous black shales.
- (*c*) Thin-bedded compact blue limestone.
- (*b*) Contorted, alternating flinty, argillaceous and quartzite beds.
- (*a*) Yellowish indurated slaty shales; siliceous sandstone, quartzite, fine quartz breccia, or coarse sandstone with pebbles.

Layers above these, as exposed at Iguana Creek and in the Mitchell, at Glenalladale, consist of variously alternating thick and thin layers of breccia-conglomerate, pebble conglomerate, sandstone with occasional pebbles, quartz grits, ferruginous conglomerate, sandstones, blue and yellow shales, sometimes containing pebbles, and thick-bedded rubbly red or grey shales, without apparent stratification, and sometimes calcareous, resembling, as remarked by Mr. Selwyn of similar bands near Freestone Creek, the "cornstones" of the Old Red Sandstone series of Britain. (Fig. 14.)

FIG. 14.—DIAGRAM OF BEDS AT IGUANA CREEK.

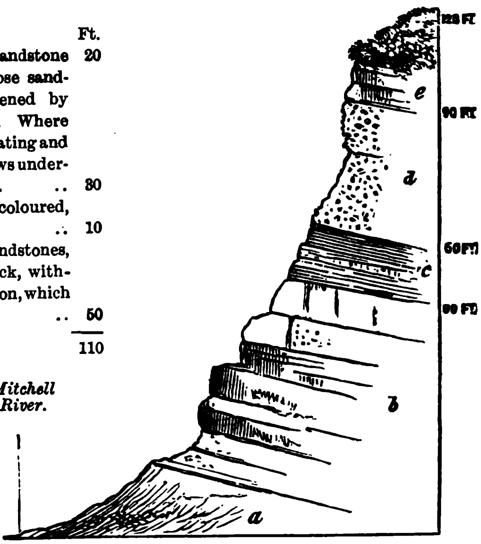


		Ft.	in.
o Up to the summit, hard siliceous yellow sandstone	about	50	0
n Ferruginous conglomerate ..	,,	1	6
m Thin bedded yellow quartzose sandstone	,,	5	6
l Quartz grit	,,	0	6
k Irregularly bedded yellow shale, with pebbles	,,	2	6
i Hard siliceous band	,,	0	6
h Pale yellowish sandstone ..	,,	2	6
g Pebble conglomerate	,,	2	6
f Blue shale	,,	0	6
e Pebble conglomerate	,,	4	0
d Shale	,,	1	0
Thin sandstone	,,	0	6
b Irregularly bedded blue shale and conglomerate ..	,,	5	0
a Breccia-conglomerate.. ..		2	6
		79	0

It was ascertained by Mr. Howitt and myself that the Iguana Creek beds are continuous to Maximilian Creek, around

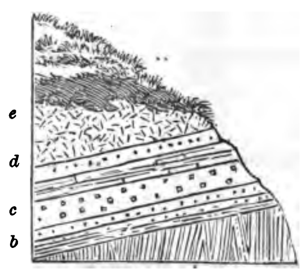
FIG. 15.—MITCHELL RIVER, ABOVE GLENALLADALE.

	Ft.
(*d*) Hard yellow and reddish sandstone	20
(*c*) Conglomerate and quartzose sandstone. In places hardened by ferruginous infiltrations. Where not so, rapidly disintegrating and forming cavernous hollows underneath the beds (*d*)	30
(*b*) Rubbly shale—red or slate-coloured, and in places calcareous ..	10
(*a*) Thick-bedded quartzose sandstones, resting on red rubbly rock, without apparent stratification, which is the lowest bed visible ..	50
	110



the flanks of the prominent ranges, composed of the Middle Devonian shales and quartzites of the Tabberabbera and Cobannah series, which here separate the Mitchell and Avon drainage-areas. At Maximilian Creek we found, resting on the edges of the nearly-vertical Devonian rocks, a sequence of slightly dipping Upper Devonian beds similar to that of the Iguana Creek layers, the lowest being conglomerates and conglomeritic sandstones, followed by felstone porphyries (contemporaneous), above which again are alternating conglomerates, sandstones, &c. (Figs. 15, 16, and 17.)

FIG. 16.—MAXIMILIAN CREEK.



(*a*) Hard crystalline quartzite lying at a high angle, but the dip is uncertain, owing to strong joints. It is penetrated by large dykes striking N. 30° E. The dip of the quartzite may possibly be N. 30° E. at 80°.

(*b*) Thick-bedded coarse sandstones with a few pebbles.

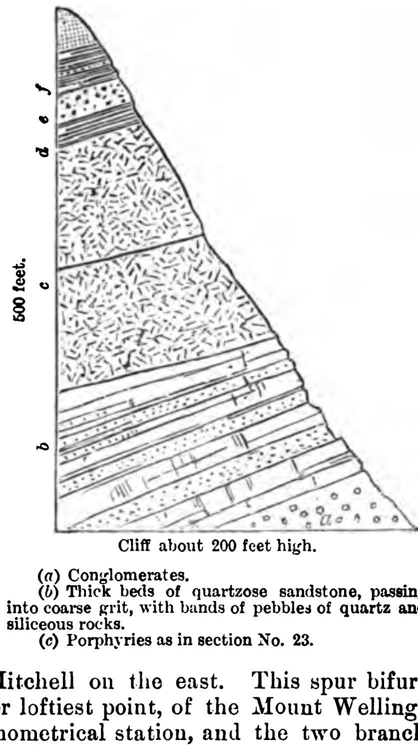
(*c*) Coarse conglomerate of quartz, indurated slate, and sandstone pebbles.

(*d*) Thick sandstones.

(*e*) Quartz porphyries; porphyritic, quartziferous, and concretionary felstones, which are in places rough and scoriaceous in appearance, owing to irregular cavities.

Further westward, at the Freestone Creek quarries, near Briagolong, I found, in shales underlying the sandstone beds of the quarries, a few plant-impressions, among which Professor McCoy identified *Cordaites Australis*, one of the characteristic fossils of the Iguana Creek beds. Below these are grey rubbly shales or "cornstones" like those previously mentioned.

FIG. 17.—SKETCH SECTION, MAXIMILIAN CREEK.



Cliff about 200 feet high.

(*a*) Conglomerates.
(*b*) Thick beds of quartzose sandstone, passing into coarse grit, with bands of pebbles of quartz and siliceous rocks.
(*c*) Porphyries as in section No. 23.

On proceeding north-eastward from here up St. George's Creek, a branch of the Freestone, the felstone sheets are found to appear from beneath the sandstones, &c.

Before describing the next point of interest—the Snowy Bluff—a short description of the physical features is advisable.

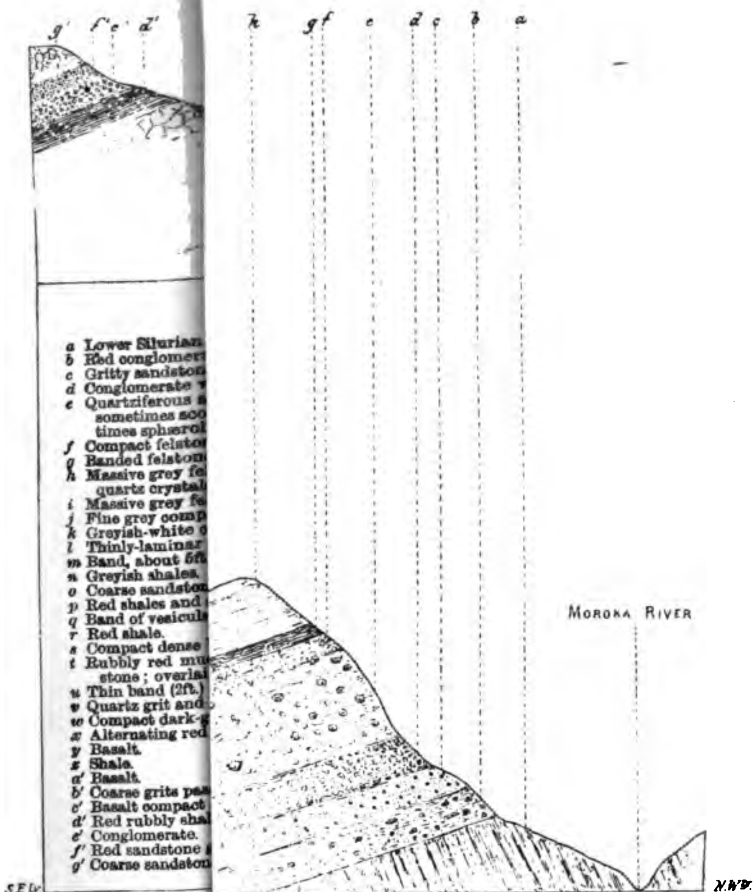
From Mount Howitt, on the Main Divide, a leading spur trends south-south-easterly, and divides the water of the Macalister on the west from those of the Wonnongatta or Mitchell on the east. This spur bifurcates at the eastern end, or loftiest point, of the Mount Wellington Range, near the trigonometrical station, and the two branch leading spurs thus formed embrace the drainage-area of the Avon River. The Mount Wellington Range itself forms the first portion of the western of these spurs, and terminates at its western extremity in a huge bluff, forming a conspicuous feature, visible from the Gippsland plains and Lakes. The spur continues westerly, but at a decreased elevation, to Mount Hump, whence it turns southerly, and, with numerous alternating high points and low saddles, gradually descends till it splits up into the numerous minor spurs sloping down to the level country between the Avon and the Macalister. Ben Cruachan, another conspicuous mountain, about 2,800 feet in height, forms one of the offshoots from this spur. The eastern leading spur from Mount Wellington, forming the divide between the Avon and the Mitchell, has a general east-south-easterly trend to Castle Hill, and then turns south-south-easterly, running out in numerous branch spurs on the low country.

The Moroka River is a branch of the Mitchell, and heads from a broad valley between Mount Wellington and Castle Hill, whence it flows north through precipitous ranges for the greater part of its length, finally turning to the east and joining the main river. A bold lofty spur, starting from Castle Hill, runs north between the Moroka and the Mitchell Rivers, and its terminal point before descending to their junction is the Snowy Bluff. At the Snowy Bluff a section was noted by Mr. Howitt and myself, showing over 2,000 feet of well exposed layers, having a slight southerly inclination, and resting on the abraded edges of the nearly vertical Silurian rocks. Here, again, the lowest beds, immediately on the Silurian, are conglomerates and conglomeritic sandstones, on which rest quartziferous and porphyritic felsites and massive bedded felstones, clearly contemporaneous, followed by alternations of laminar and rubbly shales, sandstones, grits, rubbly mudstones, and conglomerates, with intercalated contemporaneous layers of basalt (melaphyre); the uppermost bed noted is a coarse conglomeritic sandstone. (Fig. 18.)

These Upper Palæozoic rocks constitute the Snowy Bluff, Mount Kent, and Castle Hill Range, and the country westward of it; the lower eastern slope of the range, towards the Wonnongatta, being Silurian and Granite.

The boundary line between the Upper Palæozoic and the older rocks from Castle Hill to Freestone Creek has not been examined; but there is no reason for doubting the general identity in geological position of the Snowy Bluff beds with those of Freestone and Iguana Creeks, which have been shown to be of Upper Devonian age.

At the Avon River, where it emerges from the mountainous country, above its junction with Valencia Creek, occur varying bands of thick and thin bedded fissile, purple, brown, and yellowish micaceous sandstones, and purple or brick-red rubbly mudstones, "cornstones," with other varieties of sedimentary rocks, the whole forming a group known as the "Avon Sandstones," in some of the red and yellow sandstones of which was found the *Lepidodendron* (*Bergeria*) *Australe*, figured and described by Professor McCoy in the first Decade of his Prodromus of Victorian Palæontology. Professor McCoy expresses a strong opinion as to the Lower Carboniferous aspect of this fossil plant-impression; and, from my own observations, I am inclined to believe that the beds in which it is found are among the uppermost of the group, and younger than, though conformable with, the Upper Devonian beds of Freestone and Iguana Creeks. It is highly probable, therefore, judging from their stratigraphical position, that the Avon Sandstones are—as indicated by Professor McCoy, on palæontological evidence—of Lower Carboniferous age, or passage beds in that direction upwards from the Upper Devonian beds.


g' f' e' d'
h g f e d c b a
a Lower Silurian
b Red conglomer
c Gritty sandston
d Conglomerate
e Quartziferous
sometimes sco
times sphærol
f Compact felston
g Banded felston
h Massive grey fe
quartz crystal
i Massive grey fe
j Fine grey comp
k Greyish-white
l Thinly-laminar
m Band, about 5ft
n Greyish shales,
o Coarse sandston
p Red shales and
q Band of vesicul
r Red shale.
s Compact dense
t Rubbly red mu
stone ; overlai
u Thin band (2ft.)
v Quartz grit and
w Compact dark-
x Alternating red
y Basalt.
z Shale.
a' Basalt.
b' Coarse grits pa
c' Basalt compact
d' Red rubbly sha
e' Conglomerate.
f' Red sandstone
g' Coarse sandston
MOROKA RIVER
S.E.ly.
N.W.ly.

LUFF.

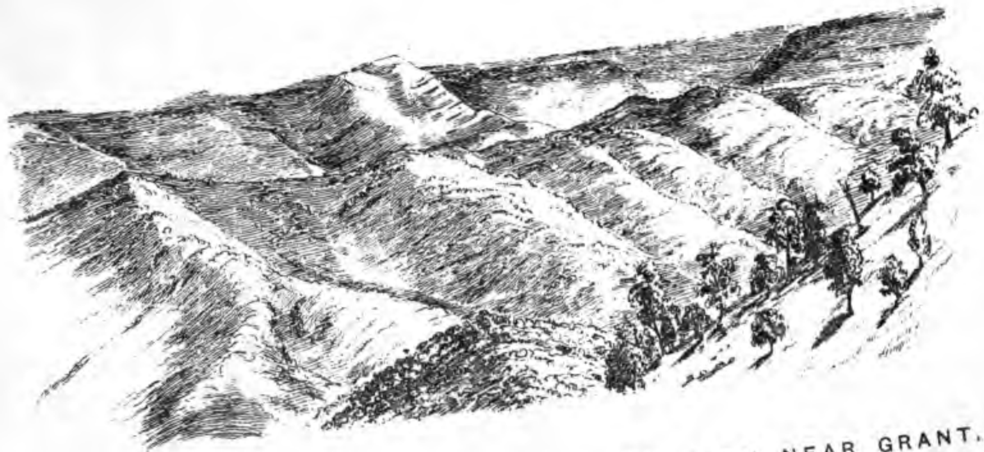
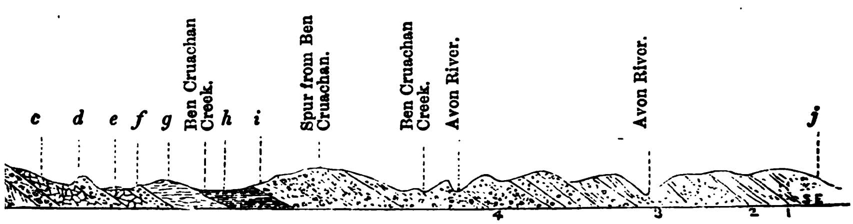


FIG. No. 18.—THE SNOWY BLUFF—SEEN FROM NEAR GRANT.

At the western boundary of the Upper Palæozoic rocks, on the east side of the Macalister River, near Glenmaggie, their lowest beds resting on the Silurian, are conglomerates, felstones, &c., analogous to those on the eastern margin. Between Glenmaggie and Glenfalloch, further up the Macalister, a tongue of Silurian rocks, extending from the main western mass of that group, projects into the Upper Palæozoic area as far as Mount Hump, on the divide between the Macalister and the Avon. The lowest Upper Palæozoic rocks flanking this Silurian projection on either side are coarse conglomerates and breccias, followed by alternations

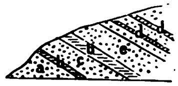
FIG. 19.

Sketch Section, showing general sequence of Upper Devonian rocks along line of dip from the Silurian boundary, north-west of Ben Cruachan to near upper end of Little Plain.



a Silurian. *b* Upper Devonian conglomerate. *c* Melaphyres. *d* Conglomerate (containing melaphyre boulders). *e* Melaphyre. *f* Coarse sandstone. *g* Porphyry. *h* Hard fissile gritty shales. *i* to *j* Alternating conglomerates, thick and thin bedded.

Enlarged Sections, illustrative of rocks between *i* and *j* in above Section.

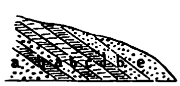


No. 1.

a Thick-bedded coarse-jointed micaceous sandstone.
bb Soft purple shale bands.
c Hard fine purple-brown micaceous sandstone.
e Fissile brown micaceous sandstone; part of the band ferruginous and full of cavities.
d Alternate bands of purple rubbly shale and hard purple-brown micaceous sandstone.

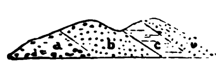
No. 2.

aa Thick-bedded hard fine brown sandstone.
bb Finely gritty purple-brown rubbly shales.
c Light bluish-grey finely gritty shale.
d Hard brown sandstone.
e Thick-bedded light bluish-grey coarse siliceous sandstone.



No. 3.

a Rubbly purple-brown shale.
b Hard coarse siliceous sandstone with fine-grained brown layer.
c Fine hard rubbly siliceous grit.
d Hard fine purple-brown sandstone, much jointed.
e Hard rubbly bluish-grey shale.
f Hard fine grey siliceous sandstone with fissile bands.



No. 4.

a Conglomerate.
b Coarse sandstone, showing false bedding and containing patches and bands of conglomerate.
c Dark-red rubbly fine sandstone and gritty shale.
d Coarse sandstone.

of other forms of sedimentary rocks and contemporaneous traps (felsites, melaphyres, &c.). Huge masses of coarse dark-red breccia-conglomerate are here and there to be seen lying loose on the Silurian rocks near the boundary between the two formations.

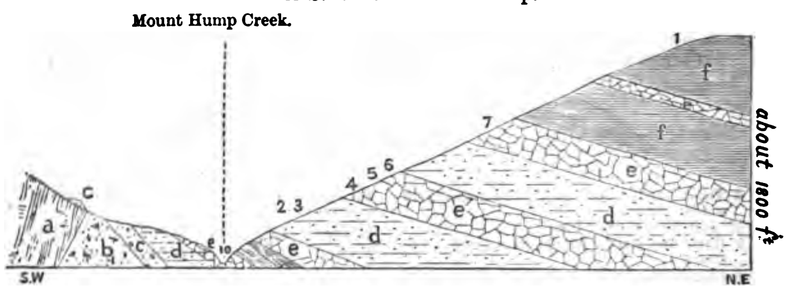
In following up the Avon River to its sources near Mount Hump and Mount Wellington, I obtained a tolerably plain descending sequence of layers from the lepidodendron beds through various thick and thin bedded conglomerates, sandstones, and shales, down to conglomerates (containing boulders of melaphyre) under which lie bedded felsites and melaphyres, finally underlaid by coarse grey conglomerate resting against the Silurian. (Fig. 19.)

Of the igneous rocks associated with the Upper Palæozoic sedimentary beds in the valley of the Avon, some are clearly contemporaneous whilst others may be intrusive. The examination made has been of too cursory a nature to enable reliable conclusions to be arrived at.

In their lithological character they are most interesting. Those that are unmistakably contemporaneous are principally melaphyres, exhibiting various degrees of alteration, due to natural chemical action. (Fig. 20.)

FIG. 20.

Section showing apparent sequence of beds in head of branch of the Avon River S.E. from Mount Hump.



a Silurian. *b* Granite. *c* Breccia-conglomerate. *d* Sandstones and shales. *e* Melaphyres and basalts. *f* Porphyry-felsite. 1, 2, 3, &c., Nos. of specimens examined microscopically by Mr. A. W. Howitt.

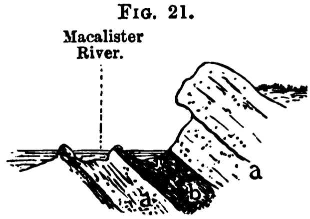
In some of them the basaltic character is still recognisable, while in others the original structure is quite obliterated. They evidently represent the results of the volcanic activity of the period. Besides melaphyres there are quartz-porphyries, felsites, &c., of various kinds. The summit of the western bluff of the Mount Wellington Range is composed of fine quartz felsite; and specimens of serpentine and diallage rock have been brought from the country lying to the north. The results of microscopic examinations made of some of these rocks, by Mr. Howitt, will be found in the Geological Progress Report No. V., page 144 and following.

Northward from the Mount Wellington Range, in the country watered by the Macalister, and its branches, the Barkly and Wellington Rivers, none of the igneous layers have been observed *in situ*, and the rolled fragments all appear to have come from the Wellington Range. Conglomerates, also, are of rarer occurrence and finer in character than in the Avon valley.

The prevailing forms are brown micaceous sandstones, purple rubbly shales, some bands of hard grey gritty shales and flags, and a few fine conglomerate bands.

A general south-easterly dip at a low angle is observable in the Avon, and in various places in the Macalister valley; but there are numerous local exceptions. The most abnormal dips as regards direction and rate of incline noted by me are in the Macalister near Glencairn, where there are red rubbly mudstones and shales on coarse yellowish-brown sandstones, dipping in one place S. 60° W. at 38°, and in another, a short distance away, S. 73° W. at 41°.

FIG. 21.

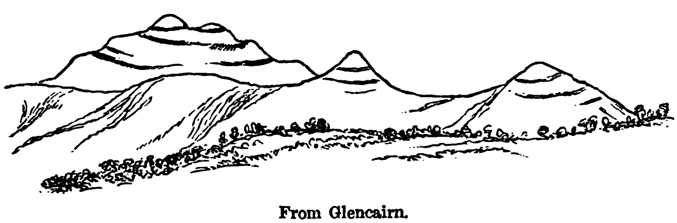


a Brown micaceous sandstone.
b Purple rubbly shales.

The dip obtained furthest north was in the Barkly River, close to the western line of contact of the Upper Palæozoic with the Silurian. The former consist here of hard gritty flags overlaid by sandstones and red rubbly shales dipping S.E. at 8°. (Fig. 21.)

At the Crinoline, a very conspicuous hill about 4,500 feet in elevation, between the Macalister and the Wellington, the rocks are nearly horizontal, and the outcrops of the harder beds on either side of the hill form a succession of cliffs, with steep grassy slopes between, which give the hill the appearance to which it owes its name. (Fig. 22.)

FIG. 22.—"The Crinoline."



From Glencairn.

From the summit of this hill the same appearances are visible in the ranges on either side of the Macalister and Wellington as far as the eye can discern; cliffs and buttresses of the harder rock-bands forming nearly horizontal broken contour lines round the spurs of the mountains. The general appearance of the

mountains and the character of the detritus in the river beds indicate that the upper Palæozoic rocks of the Macalister extend up to and over the Main Divide whence the various sources of the river take their rise, and are connected with the Upper Palæozoic area of Mansfield, between the Delatite and Broken Rivers. This, however, cannot be proved without proper examination of the country being made.

The general character of the more mountainous portion of the Upper Palæozoic area is very rugged. The rivers and creeks frequently flow between perpendicular cliffs and through deep rocky ravines, while many of the ridges and high points exhibit very precipitous sides and craggy bluffs. The ranges and slopes in the Avon valley are fairly clothed with large timber, and the hollows support a tolerably dense scrub. The soil is, however, as a rule, poor and gritty, though in localities where the melaphyre bands crop out there are very small areas of a tolerably rich soil, resulting from their decomposition.

The ranges in the Macalister valley are open and grassy, steep, and sometimes precipitous, and for the most part thinly covered with inferior timber. On the high lands the vegetation assumes a sub-alpine character, and is composed chiefly of stunted scrub, heath, snow-grass, mosses, and various herbs.

The Upper Palæozoic area of Mansfield is beautifully park-like in character, well grassed, and thinly timbered with fair-sized redgums. The eminences, such as Mount Tabletop and others, have a tabular appearance, due to the almost horizontal and alternating character of the rock layers, the harder of which project in shelf-like contours round the slopes. The prevailing forms are hard, gritty, thickly-bedded sandstone; hard, gritty flags, dense brownish fine-grained argillaceous sandstones, and mudstones, or "cornstones," similar to those of the Avon.

This tract is partly hemmed in on the south-west, north-west, and north-east by lofty Silurian and Granite Ranges, through which gaps have been eroded by the streams flowing into the Delatite on the western, and the Broken River on the north-eastern, side of the valley. To the south-east the country rises, and becomes very broken and mountainous; Mount Buller, one of the highest points, attaining an altitude of 5,800 feet. This part has not been properly geologically examined, but it is evident from the boulders and pebbles of felsite, quartz-porphyry, greenstone, syenite, &c., in the beds of the rivers that contemporaneous, and, probably also intrusive, trappean rocks are associated with the sedimentary Upper Palæozoic strata near the sources of the Jamieson, Howqua, Delatite, and Broken Rivers.

From the horizontally-bedded appearance of the rocks of a great bluff, visible at a distance far up the valley of the Howqua, I felt justified in assuming, and so indicating on the Geological

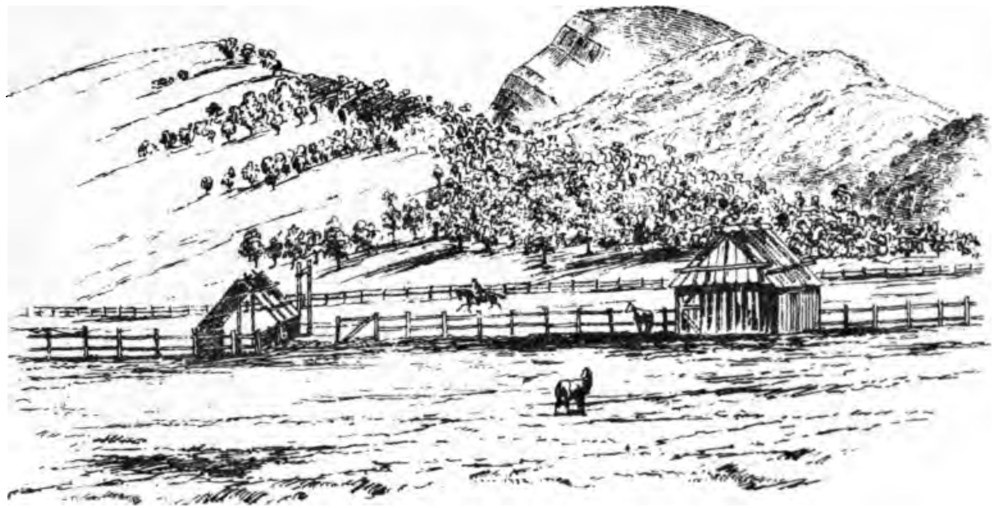


Fig. No. 23.—Mt. Tambo. From the Omeo Station.

Sketch-map, the extension of the Upper Palæozoic rocks up to the Main Divide, and their continuity with those of the Macalister country.

On the ranges between the Jamieson and the Howqua, and between the Howqua and the Delatite Rivers, are huge masses of red breccia-conglomerate resting on the Silurian rocks, near the boundary of the Upper Palæozoic, in the same manner as in the Avon country.

The general resemblance to one another of the rocks in various localities throughout the eastern Upper Palæozoic area justifies the general provisional reference of the whole series to the Upper Devonian period, which the Iguana Creek beds serve to identify.

At Mount Tambo, on the Main Divide, occurs a large outlier, of Upper Palæozoic rocks, resembling, in general lithological character, the Avon Sandstones, and containing, according to Mr. Selwyn, similar plant-impressions.

Mr. A. W. Howitt's map, and his accompanying essay on the Devonian rocks of North Gippsland, supply the following information as to the character and mode of occurrence of this outlier.

The foundation on which the Mount Tambo beds rest is granite on the south, Upper Plutonic quartz-porphyries, &c., on the south-east and west, and metamorphic crystalline schists on the north-east. A small vestige of the Middle Devonian limestones of the Bindi group also passes under the Mount Tambo beds, at the south-eastern margin of the latter.

Ascending Mount Tambo from the north-eastern side, the first layer of the Upper Palæozoic series, resting on the metamorphic rocks, is a coarse conglomerate, without any sign of stratification, and composed of rounded fragments of quartzite, quartz, and indurated slates, with a few boulders and pebbles of siliceous quartz-conglomerate.

This conglomerate bed becomes finer upwards, and passes into a coarse reddish-yellow grit with sub-angular fragments of quartz and indurated slate, overlaid by a bed of about 50 feet in thickness of rubbly brick-red or purplish rock, showing little sign of stratification. On this are sandstones, about 40 feet thick, followed by about 120 feet of coarse to fine conglomerate ; then a second bed of red rubbly rock overlaid by coarse conglomerate, forming the summit of the mountain. The total thickness of these beds is nearly 1,500 feet, and their dip is south-westerly at from 37° to 45°. Following the descending ridge south-westerly in the direction of the dip, the last-mentioned conglomerate is followed by yellowish sandstone and sandy shales, with a covering of conglomerate. (Fig. 23.)

A gradual change commences from here ; the beds become finer and more argillaceous ; the dip becomes more vertical, and is finally reversed to the opposite direction, when it gradually becomes more

horizontal. The beds resting against the granite on the south side are flinty shales dipping north-easterly, and slightly metamorphosed by silicification. The Mount Tambo beds thus form the remaining vestige of a synclinal fold of Upper Palæozoic rocks resting in a trough or hollow of the Lower Palæozoic sedimentary and igneous rock foundation.

Mr. Howitt also mentions the occurrence of outlying masses of the coarse breccia-conglomerates of this series resting on older rocks in various localities eastward of the Tambo, on the slopes of the Cobberas, and other localities; also a patch of nearly horizontally-bedded rocks, resembling those of Ignana Creek, in a deep valley at the sources of the Bem River eastward of the Snowy River.

On the Wild Duck Creek, between Sandhurst and Heathcote, is a patch of conglomerate resting in a basin on Silurian rocks. The age of this conglomerate, whether Upper Palæozoic or Mesozoic, has not been determined, but Mr. Selwyn describes the character and arrangement of the materials as being suggestive of a marine glacial action, *i.e.*, that the fragments composing the conglomerates were conveyed from distant sources by icebergs. Other small patches of similar conglomerate occur in various localities.

CHAPTER VI.

Conjectures as to Geological History in Palæozoic times. Lower Palæozoic formations. Snowy River Porphyries. Middle Devonian Rocks. Upper Palæozoic beds.

Having so far generally described the stratigraphical relations and lithological character of the great Palæozoic or primary group, which constitutes the rock foundation of Victoria, it may be well to venture, as suggestions for discussion, some conjectures as to the history and nature of the geological changes which took place up to the close of the Upper Palæozoic era. The chain of evidence is of a rather broken character, and many of the theories advanced may be refuted when further testimony shall have been obtained. Certain data are nevertheless available, which, though imperfect, consist, as far as they extend, of ascertained facts. The reasoning on these facts may be incorrect, and the theories advanced may ultimately prove untenable, but their consideration can do no harm, as the discovery and rectification of mistakes form important factors in the progress of scientific knowledge, and the advancement by any person of an incorrect theory, based on a few facts, may often lead to the acquirement of sounder knowledge, by inciting inquiry for rebutting evidence in the shape of further facts and more exhaustive reasoning on the part of others.

The general deductions as to the geographical history of this country do not differ, except in minor details, from the conclusions arrived at as to that of other parts of the world.

In the first place, we see that our oldest rocks, the Silurian strata, must have been deposited in horizontal layers to a thickness, as generally estimated, of about 30,000 feet. Great as this thickness appears, it is no more in proportion to the earth's bulk than a thickness of stout paper around a globe of 16 inches in diameter. The general character of the Silurian rocks suggests that they were deposited in deep water in such broad depressions of the earth's crust as then existed. Their component materials were derived from the wearing away by water of still older igneous, and perhaps also sedimentary, rocks, all vestiges of which *in situ* have been obliterated. As shown in a previous chapter, it is very improbable that the foundation on which they were deposited consisted of granite such as we now see underlying them, the present form of that rock being clearly the result of subsequent deep-seated Plutonic action. Assuming as correct the theory that the earth was once molten or red-hot, and that it was only after

it had sufficiently cooled that water could rest upon its surface, it is easy to conceive that there would be a vast quantity of loose incoherent material, volcanic dust, ash, &c., which would at once be taken up and temporarily held in suspension by the water when the latter first settled on the earth. Add to this the heated condition of that water the natural chemical and mechanical operations which must have ensued, and the length of time they continued in action, and the formation of so (comparatively) thin a layer—resulting from the re-distribution of pre-existing matter—as the total thickness of all the sedimentary Palæozoic formations of the earth's present crust would amount to, is easily accounted for.

Recent researches have shown that in deep seas, even at the present day, there are frequently vast "mud clouds," the deposit of which on the bottom is exceedingly slow, and it may well be imagined that the water which first enveloped this earth may have for a time been able to hold in suspension the materials of all the sedimentary rocks now visible. The probable greater bulk of the earth, and the larger amount of water on its surface, has already been alluded to.

Consequent on the diminution of the earth's bulk through contraction in cooling, the next processes were the folding and corrugation of the layers which had been deposited, their metamorphism, and invasion or partial absorption by molten igneous matter.

There is no reason to believe that these movements, as regards the Lower Palæozoic strata, took place simultaneously all over the earth, or that they were of a sudden character; they may, for instance, have commenced during the Lower Silurian period, and have been in gradual progress during the actual deposit of the Upper Silurian rocks. The action of regional metamorphism may also be regarded as having taken enormous lapses of time to accomplish its effects, and so also the consolidation of the molten masses into the forms of granite, porphyry, &c., was no doubt the work of incalculable ages. Neither was the Plutonic action, of which these rocks are the results, confined to one period, for as already shown there is evidence of its occurrence at distinct intervals. It was from the folding and squeezing together of the Lower Palæozoic rocks that the first rude geographical distribution of land and water surfaces properly resulted. The broader anticlinal and synclinal undulations formed respectively the elevated land surfaces and the depressions occupied by the sea. This period witnessed the elevation of the general axial line of the Australian Cordillera, not as we now see it, in the form of a narrow but well-defined and tortuous ridge, but as a broad elevated broken plateau, having no defined water-shed line, but forming a continuous land surface from Tasmania to New Guinea.

With the appearance of land surfaces commenced littoral and terrestrial denudation; the uptilted edges of the rock-bands were abraded and worn down; their entire removal in places caused the first appearances of granite at the surface; and the formation of new rocks began to take place in the sea beds.

The next great geological development, as far as Victoria is concerned, appears to have been the appearance of the great chain of terrestrial volcanoes, which, as shown by Mr. A. W. Howitt, marked the Lower Devonian period in this country, and the ejected lava and ashes of which, though in an altered form, as well as the sites of eruption, are recognisable in the belt of igneous rocks known as the Snowy River porphyries. As already stated, the evidence obtained by Mr. Howitt indicates purely terrestrial conditions as having accompanied the development of this group, and it may in consequence be inferred that the land was more elevated above sea-level then than it is now, as the terrestrially-formed felsitic ash beds of the Snowy River group can be traced to within a very slight vertical height above the existing sea-level. That the mountains attained a far greater altitude than now and have been subsequently worn away is evident, if such points as the Cobberas, 6,000 feet high, be but the denuded stumps of the ancient volcanic cones. This volcanic chain probably resembled, on a smaller scale, that now in action in the Andes of South America. Its position is worthy of notice, as it includes portion of the present Cordillera, and extends southward from where the latter now diverges suddenly to the west at Forest Hill directly in the line of prolongation of the general course of the Cordillera through New South Wales from Mount Kosciusko to Forest Hill, and the general bearing of the chain from Forest Hill to the mouth of the Snowy would, if produced, run through Tasmania. Whether the crest of the land-surface which once connected Australia with Tasmania was on this line or further to the westward is a matter of speculation, but it does not appear unlikely that the igneous belt extended to Tasmania, either as a wholly terrestrial or partially marine chain of volcanoes. If the former, the connexion as a land surface was probably severed by denudation early in Middle Devonian times. It would be interesting to ascertain whether, in the older igneous rocks of Tasmania, the same evidences are observable as those which justify the conclusions arrived at by Mr. Howitt as to the origin of the Snowy River belt of porphyries.

The development of this group must have been the work of an immense lapse of time, and it is very likely that, during that period, none of the existing area of Victorian land surface was under water, so that there was no contemporaneous marine deposit in process of formation within that area, but rather a removal of material by the action of littoral, fluviatile, and very likely, terrestrial glacial denudation, and the erosion of deep troughs and

channels in the Silurian and granitic rocks. The general principle may here be stated, that in past geological times as now, wherever a land surface rose above the sea, the action of denudation was constantly removing material from such surface to the sea, where, according to circumstances, it was re-distributed in fresh forms. Briefly stated, emergence above the sea implies loss; submergence, accumulation. The close of the Lower Devonian period appears to have been marked by a general submergence of the land surface, naturally accompanied by encroaching littoral denudation, and the erosion of bays and inlets, but without immediate cessation of the volcanic activity which had been at work for so long, as evidenced by the igneous character of the earlier aqueously-arranged Middle Devonian beds of Buchan. Finally, the volcanic fires appear to have become extinct, and the land to have been depressed to a great depth beneath the ocean, in the bed of which the limestone deposits then accumulated in the deeper hollows in the older rocks; and while the limestones were in progress in some places, beds of a different character—the shales, slates, quartzites, &c., of Tabberabbera—were being laid down in another. Further contraction of the earth's bulk and other influences caused the uplifting, folding, compression, and partial metamorphism of these new layers, whose basset edges were, in their turn, subjected to abrasion, and partly denuded simultaneously with the still further denudation of the Silurian rocks. These Middle Devonian formations have only been identified in the eastern portion of the colony, and in the central portions, or on the southern and eastern slopes of the great Lower Palæozoic mass. Any rocks of this age that may have been deposited on the western, north-western, and south-western slopes have been totally removed by denudation, or, if any vestiges do remain, they are concealed by newer formations.

The striking stratigraphical unconformity between the Middle and Upper Devonian rocks has been already noticed; the former are sometimes nearly vertical, while the latter are, in many places, seen to rest almost horizontally on their upturned edges. This seems to indicate an emergence of the land, and a long continuance of terrestrial and littoral denuding action on the Middle Devonian and older rocks, subsequent to their plication and partial metamorphism, and prior to the commencement of the beds of the Upper Palæozoic group, in which are included the Upper Devonian rocks.

It has been shown how the rocks of the Upper Palæozoic division are most extensively developed in two great groups—one that of the Grampian sandstones in the western portion of the colony, and the other comprising the belt extending from Iguana Creek to Mansfield, in the central eastern district. In his work, published in 1866, Mr. A. R. C. Selwyn indicates the probability that these two masses are respectively the western and eastern remnants of a great anticlinal arch of Upper Palæozoic rocks which

once overspread the whole of the intervening central portion of Victoria, but of which all but the two extremities have been since removed. In support of his views, Mr. Selwyn refers to the westerly inclination of the Grampian sandstone beds, with their abrupt east-facing precipices on the one side, and the west-facing precipices of Timber Top, Mount Wellington, and Ben Cruachan on the other, and he also cites the occurrence of isolated patches of Upper Palæozoic rocks in the intervening country. At the time this was written, little was known of the geology of the eastern Upper Palæozoic belt, and the aspect, at a distance, of such hills as Ben Cruachan and Mount Wellington favoured Mr. Selwyn's belief. The results of subsequent investigations, however, justify a considerable modification of the views expressed by Mr. Selwyn in 1866. The facts as regards the modes of occurrence of the Upper Palæozoic rocks are briefly as follows :—1. The Grampian sandstones or western group flank and decline from the western slopes of the great central Lower Palæozoic mass; their original margin of contact with the latter has been cut through by denudation, and their eastern portion, wherever it may have once extended to, has been removed ; their lithological character and the dip of their beds has favoured the development of the precipitous character of their eastern faces.

2. The eastern group occupy a long and deep trough, hollowed back far into the central mass of Lower Palæozoic rocks, which form steep margins on all sides but that towards the coast.

3. The outlier at Mount Tambo occurs similarly, though its containing hollow is at a greater elevation than that of the last-mentioned group, and has been cut off at either end by denudation.

4. With respect to intervening patches, that at Wild Duck Creek is at a very low elevation above the sea, and I do not know of a single instance where a capping of Upper Palæozoic rocks has been met with on any of the higher mountainous country between Mount Wellington, in Gippsland, and Mount William, in the Grampians. The few conglomerate patches which do occur are at elevations considerably under 2,000 feet, and appear more nearly related to the Mesozoic rocks, which will be hereafter described, than to the Upper Palæozoic.

There can be no doubt whatever that during the Upper Palæozoic epoch the country was submerged below the sea to a depth not less than 5,000 feet lower than it is now, and that previous to such submergence terrestrial and littoral denudation had eroded in the Granite, Silurian, Lower Devonian, and Middle Devonian rocks, the troughs and hollows which were afterwards filled by the Upper Palæozoic beds. At the same time there is no reason to infer that the entire central rock mass was submerged.

Considering that the materials constituting the Upper Palæozoic sedimentary deposits must have been derived from the waste of a land surface, and that that land surface was evidently, especially in the case of the eastern group, at no great distance, it appears far more likely that the mountain masses in the central and eastern parts of the colony, between the heads of the Macalister and Mount Ararat, between Snowy Bluff and Mount Tambo, and eastward from Mount Tambo, were very much higher than now, and projected above the ocean, by whose waters the Upper Palæozoic layers were deposited in the open sea or in the deep inlets thereof.

I do not, therefore, believe that the present Main Divide in its central portion, between the head of the Macalister and the meridian of Melbourne, was ever covered by the Upper Palæozoic rocks, but it is nevertheless most likely that they flanked the southern slopes of the mountain mass, and overspread the entire area from the Grampians round to near Wilson's Promontory. Possibly Australia and Tasmania were then separated by the ocean, and the Upper Palæozoic layers overlaid Wilson's Promontory and the South Gippsland country, and thus formed a continuous flanking deposit from the Grampians to the Macalister, but I am nevertheless inclined to believe that a great elevated ridge of granite and Silurian rocks still existed, either above water or only slightly submerged, extending from the Main Divide approximately on the direct course of the Southern Spur, from Mount Baw Baw to Wilson's Promontory, and thence to Tasmania. This ridge may have been already somewhat lowered by denudation in the region now occupied by the South Gippsland Ranges, and over that portion, if anywhere, flowed the waters of any strait that may then have separated Australia from Tasmania.

Whatever their geological relation, and that is very close, if not identical, the Grampian sandstones and the rocks of the eastern area are geographically distinct groups, and show very clear evidence of a difference in the conditions of their modes of deposit. The fine to moderately coarse arenaceous character of the Grampian sandstones, the scarcity of conglomerate bands, and the well water-worn character and comparatively small size of the pebbles, where they do occur, coupled with the geographical relations of their beds to the older rock masses, all tend to indicate that they were deposited at some distance from the coast line of the period in a wide open sea, which then covered a vast area to the north, south, and west. They were deposited against the western, southern, and, possibly, also the northern, flanks of the great central Lower Palæozoic mountain mass, which had not been then so much denuded as we now see it, and which projected above the ocean of the period. The eastern edges of the Grampian beds, which rested immediately against the older rocks, and

which would naturally have included the layers of a more conglomeratic character, have been entirely removed. If the patch at Wild Duck Creek, near Heathcote, is correctly classed as Upper Palæozoic—of which there is some doubt—deposits of that age must have flanked the northern slopes of the older rocks, and overlaid a large portion of the area now occupied by the Murray tertiaries.

The rocks of the eastern Upper Palæozoic area show evidence of different conditions in their deposit from those observable in the Grampian Sandstones.

Taken as a whole, the belt of rocks from Iguana Creek to Mansfield occupies a deep trough, or long indentation in the older rocks, which constitute its margins on the west, north, and east. The head of the indentation appears to be represented by the Mansfield valley, and if so the Main Divide of the Upper Palæozoic period was further north than the present one, and probably in the position now occupied by the Strathbogie Ranges. This will be further referred to during description of the Tertiary formations. The deposit of the Upper Palæozoic rocks in this district was restricted latterly within comparatively narrow limits; the proximity of the land surface on either side is evidenced by the coarse breccia-conglomerates along the edges, and the character of the plant impressions discovered in some of the beds. While they were being laid down, the boundary Silurian and granite rocks, which formed the land surface, evidently reached a very much greater elevation than at present, and projected above the sea.

There would also appear to have been two distinct volcanic districts now represented by the most elevated parts of the Upper Palæozoic belt—one in the country lying between the Jamieson and King Rivers, north of the Main Divide, and another on the south, between the heads of the Wonnangatta and the lower part of the Macalister, as the upper portion of the latter river appears to contain in its bed no rolled fragments of igneous rock that have come from the direction of the Main Divide, nor do such rocks appear *in situ* far to the north of the Wellington Range in the Macalister drainage-area.

The general geological appearances suggest the idea that, at the commencement of the Upper Devonian period, a deep fiord or sound, between very lofty and precipitous mountain ranges, extended inland from the Southern Ocean to what are now the southern bases of the Strathbogie Ranges; the axial line of the western range was approximately from the Strathbogie Ranges to Wilson's Promontory, and that of the eastern from the Strathbogie Ranges to between Bairnsdale and the Snowy River.

The tongue of the Upper Palæozoic rocks, formed by the extension of the Iguana Creek beds in the Mitchell valley up to Tabberabbera, seems to represent a minor inlet on one side of where the great fiord debouched on the open ocean.

The land was in process of submergence, and materials washed from the sides of the fiord, by terrestrial and littoral denuding action, were deposited and arranged in its bed; this arrangement was probably aided by tidal action, which would exert a powerful influence in such narrow confines.

During such deposit volcanic activity, which had been quiescent during the latter part of the Middle Devonian period, again broke forth and produced the contemporaneous igneous sheets. With the sinking of the land this filling up process, by aqueous deposit and lava-flows, was continued to the extent of several thousand feet, and by the time it was accomplished the mountains of the land surface on either side had been greatly reduced in height by denudation, though they still rose above the ocean. The denudation to which both Lower and Upper Palæozoic rocks have been subjected since the formation of the latter is incalculable, and has exerted the most remarkable effect in obliterating from extensive tracts every vestige of the Upper Palæozoic rocks which once overspread them.

The Mount Tambo outlier is apparently a portion of the deposits distributed in another fiord similar to that last described, and separated from it by a mountainous land surface.

It is not to be supposed that the height of over 4,000 feet, to which we now find the Upper Palæozoic rocks in Victoria, represents the level to which they accumulated for any considerable distance away from the shore-line of their period. The thickest deposits were evidently accumulated at no very great distance from the land surface, whence their component materials were derived, and the beds sloped away or thinned out seaward in every direction from the flanks of the older rock foundation on which they were deposited.

The beds generally have been comparatively very little affected by upheaval or lateral compression, and in many cases their slope appears to be that at which they were originally laid down. A certain amount of uplifting and compression has certainly taken place, but to an insignificant extent compared with what the older rocks have been subjected to.

CHAPTER VII.

Mesozoic Rocks—Relations between Upper Palæozoic and Mesozoic Rocks of Victoria with rocks of New South Wales. The Bacchus Marsh Sandstones. Mesozoic Rocks of the Wannon, Cape Otway, Western Port, and South Gippsland. Coal-seams. Fossils. Conjectures as to Geological History.

Before proceeding to describe the Mesozoic rocks it is necessary to consider what geological changes took place previous to their formation, and subsequent to that of the Upper Devonian.

With the exception of those beds of the Avon Sandstones which contain *Lepidodendron*, and which have been shown to be very slightly, if at all, removed from Upper Devonian, no rocks have yet been found in Victoria that exhibit any kinship to the true Carboniferous rocks. No fossils have been found in the Grampian Sandstones, and it is possible they may be the equivalents of the New South Wales Carboniferous rocks; as before stated, they have been provisionally classed, on stratigraphical evidence, under the general term of Upper Palæozoic, along with the Avon Sandstones and the Iguana Creek Upper Devonian beds. The geological position of the New South Wales coal measures, whether Palæozoic or Mesozoic, was for a long time a disputed question amongst geologists, but the weight of evidence is now almost entirely in favour of their being classed with the true Carboniferous (Upper Palæozoic) series.

Their equivalents have not been identified as surface rocks anywhere in Victoria, and if they occur at all (still assuming the Grampian Sandstones as older than they), it must be beneath the Mesozoic or Tertiary deposits.

There appears to be a general consensus of opinion that the New South Wales Carboniferous rocks, whose beds contain the characteristic fossil plant-impression *Glossopteris Browniana*, are younger than the so-called Upper Palæozoic, and older than the Mesozoic rocks of Victoria, whatever differences of opinion may exist as to the precise geological position of either of the three groups.

Sir R. Daintree, in his work on the Geology of Queensland, points out that the rocks of the Northern Carboniferous (Palæozoic) area there contain *Glossopteris* (which is there, in his opinion, without doubt a purely Palæozoic form), but no *Tæniopteris*, whereas in the Mesozoic coal measures of Victoria, Richmond River, in New South Wales, and the southern coal-field of Queensland, *Tæniopteris* is abundant, but no *Glossopteris* has ever been found.

Mr. Charles Wilkinson, Government Geologist of New South Wales, informs me that *Glossopteris* is found in beds-lying *between* layers which contain distinct Carboniferous (Palæozoic) fossils, and has kindly furnished me with the subjoined table, showing the approximate relations of the New South Wales and Victorian Mesozoic and Palæozoic rocks. As Mr. Wilkinson's classification is based upon long practical experience in both colonies, it is probably the most correct that can be arrived at.

		Victoria.	New South Wales.
Mesozoic.		Carbonaceous (? Oolitic) rocks of the Wannon, Cape Otway, Western Port, and South Gippsland.	Clarence River beds.
		Tæniopteris Daintreei.	
		No recognised equivalents.	Wyanamatta beds.
		Bacchus Marsh Sandstones.	Hawkesbury Sandstones.
		Gangamopteris.	
Palæozoic.	Permian.	No equivalents.	Upper Coal Measures of Newcastle, containing *Glossopteris*, which does not occur in any beds above these.
	Carboniferous.	No equivalents.	Marine beds. Carboniferous fossils.
			Lower Coal Measures. *Glossopteris* and *Phyllotheca.*
			Lower Marine beds. Carboniferous fossils.
		? Upper beds Avon Sandstones.	Lepidodendron beds.
		Devonian.	Devonian.
		Upper Silurian.	Upper Silurian.

Equivalents of the New South Wales Carboniferous rocks may or may not have once covered portion of Victoria, but if they did every trace of them as surface rocks has since been removed.

The only areas which they can possibly underlie are—1st. The broad strip of Mesozoic and Tertiary tracts in south-western Gippsland, from the Mitchell River to Western Port, between the coast line and the boundary of the Palæozoic rocks. 2nd. Portion of the district, consisting of Mesozoic and Tertiary or Volcanic tracts, between Port Phillip and the Glenelg. 3rd. The great Tertiary tract in the north-western part of the colony.

Whether they do underlie these areas or not does not alter the fact that between the completion of the Upper Devonian formations (the Avon Sandstones, Iguana Creek and Mount Tambo beds), and the commencement of the Mesozoic beds of South Gippsland, Cape Otway, and the Wannon, a vast interval of time elapsed, during which the Carboniferous rocks of New South Wales were being formed. If rocks of the latter group were deposited in Victoria during that period, a further space of time was occupied in subsequently removing them ; but if such strata were not laid down in Victoria, it can only be assumed that the period during which they were being formed in New South Wales was occupied solely in the denudation and removal of previously formed rocks in Victoria.

Whatever may have been the nature of the changes which took place in the interval, it is very evident that there is a great stratigraphical break between the Upper Palæozoic and Mesozoic rocks of Victoria.

Mesozoic Rocks.

The Bacchus Marsh Sandstones.

In Mr. A. R. C. Selwyn's work of 1866, the Bacchus Marsh and Grampian Sandstones are classed as Upper Palæozoic, though the opinion is expressed that they may be younger than the Upper Palæozoic rocks of the eastern district.

The Bacchus Marsh Sandstones, however, yield fossil plants, which Professor McCoy regards as of a Triassic or Lower Mesozoic type, and I feel justified in separating them from the Avon River and Iguana Creek beds of Gippsland, the fossil flora of which has an Upper Palæozoic aspect. At the same time, the characteristic fossil plants of the Bacchus Marsh group have not been found in the rocks of the other Victorian Mesozoic areas, nor have the fossils common in the latter been found in the former, and on this account the Bacchus Marsh beds are classed separately from those of Western Port and Cape Otway. The Bacchus Marsh Sandstones occur between the Werribee and Lerderderg Rivers, a short distance above their confluence at Bacchus Marsh, and extend in disconnected areas, much covered by volcanic layers, up the Werribee valley, as far as Greendale and Ballan. They consist principally of coarse to fine whitish and yellowish brown sandstones of variable degrees of hardness ; the lower beds of the series, resting on the Silurian, in many places consist of conglomerates. Outliers of conglomerate also occur capping spurs on either slope of the Silurian range separating the Lerderderg and Werribee Rivers. At Darley, a few miles up the Lerderderg from Bacchus Marsh, is a coarse unstratified conglomerate, consisting of a soft, earthy base, which

contains, amongst other fragments, sub-angular pieces of granite of a different character to any occurring *in situ* in the district. I remember to have heard the late Sir R. Daintree say that these fragments resembled no granite he was acquainted with occurring as a rock mass nearer than Queensland.

The general appearance of the conglomerates, and the character and mode of arrangement of their materials, are suggestive of transport by marine glacial action, though, as remarked by Mr. Selwyn, grooved or ice-scratched pebbles have not been observed. In this respect the Darley conglomerates resemble those at Wild Duck Creek, provisionally referred to as Upper Palæozoic. It is quite possible that the latter may be of Mesozoic age, as the absence of clear Palæontological evidence renders it impossible to arbitrarily fix their position. Patches of similar coarse conglomerates with yellow sandstones are shown on the geological maps as occurring on the Coliban River, near Kyneton, and between Kyneton and Heathcote, where the Silurian rocks are thinly capped by a conglomerate, containing pebbles of quartz, quartzite, hard sandstone, granite, and porphyry.

The fossil plants found in the Bacchus Marsh Sandstones have been figured and described by Professor McCoy in Decade No. II. of his Prodromus of Victorian Palæontology. They comprise three forms of fossil ferns, namely, *Gangamopteris angustifolia* (McCoy), *G. spatulata* (McCoy), and *G. obliqua* (McCoy). These *Gangamopteri* are referred to by Professor McCoy as being associated with the *Glossopteris Browniana* of the New South Wales coal-fields, and, as indicating the relationship of the rocks in which they are found, to the "Talchir" beds of the Indian coal-fields. From what has been further ascertained, however, it appears that *Glossopteris* is found in New South Wales in two sets of beds, between which are intercalated marine beds, containing fossils of distinctly Carboniferous (Palæozoic) aspect.

Mesozoic Carbonaceous Rocks of (1) the Wannon, (2) Cape Otway, and (3) Western Port and South Gippsland districts.

The areas occupied by Mesozoic rocks have been generally described in a previous chapter; but as it is desirable to indicate as nearly as possible the known limits of the surface exposures of these rocks, and also the areas covered by newer deposits which they may reasonably be supposed to underlie, a more detailed description of boundaries is here given for each of the three great Mesozoic areas.

The Mesozoic rocks of the Wannon make their appearance from beneath overlying Tertiary and Volcanic layers in the Wannon River, between Hamilton and Coleraine, and are visible thence westward as far as the Glenelg River, beyond which they

disappear under the tertiaries. They extend only a short distance northward from the Wannon, as at Coleraine they are seen to be bounded on the north by the trap rocks, and a short distance north of Casterton by the Metamorphic schists. Southward they are visible as far as Digby, but their actual extent south and south-west is unknown on account of their being overlapped by the wide-spreading Tertiary and Volcanic layers which constitute so large a portion of the surface area of the western district. Even in the tract where they are near the surface, the Mesozoic rocks of the Wannon district are so covered by thin Tertiary cappings and deep soil that few observations can be made as to their character or the inclination of their beds.

Soft earthy sandstones, from greenish brown or drab to yellowish white, and earthy or gritty shales, appear to be the prevailing forms. Imperfect plant-impressions are numerous in many of the bands, and some distinctly recognisable forms have been obtained. Seams of somewhat impure coal occur in the measures at Coleraine.

This portion of the country consists of beautiful open downs of great fertility, and affording rich pasturage.

The area occupied by exposed Mesozoic rocks in the Cape Otway district is bounded on the south-west and south-east by the coast line from near the mouth of the Gellibrand River to between Loutit Bay and Barwon Heads, and on the inland side by the flanking Tertiary deposits from the mouth of the Gellibrand to a few miles south from Colac, and thence round to the coast. The Mesozoic rocks of the Barrabool Hills, near Geelong, form portion of, but are separated as surface rocks by, overlying tertiaries from those of the Otway Ranges.

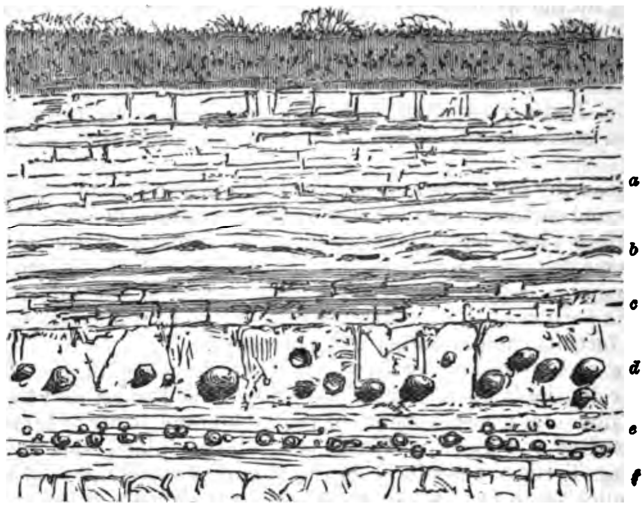
Like the Mesozoic rocks of the Wannon, those of the Cape Otway Ranges and Barrabool Hills consist principally of sandstones and shales with occasional coarse gritty beds composed of granitic detritus and fine conglomerates containing pebbles of granite, syenite, porphyry, metamorphic slate, and micha schist. At the Barrabool Hills the conglomerate beds contain pebbles of the underlying diallage rock in the vicinity, and Mr. C. S. Wilkinson also found in them pebbles of Silurian slate containing well-preserved *graptolites*. The colour of the sandstones varies from nearly white to dark greenish-grey or yellowish-brown ; the texture is generally soft and earthy, though sometimes hard durable sandstones are met with.

Throughout the whole series plant-impressions and very thin irregular seams of coal are common.

The dip is very inconstant, and the rocks are much faulted and unevenly bedded. Large and small nodules or indurated lumps, sometimes calcareous and sometimes ferruginous, are common in the sandstone. Distinct lines of stratification are often discernible

in these nodules, and they appear to be indurations resulting from natural chemical action rather than rolled fragments. On cliff faces they stand out from the weathered containing sandstone, presenting the appearance of a number of half-embedded cannon balls. (Fig. 24.)

Fig. 24.



a Yellowish-brown and greyish-brown sandstones.
b Thin patches of coal.
c Sandy shales and sandstones.
d Hard nodules standing out from the rocks.
e Smaller nodules.
f Sandstones.

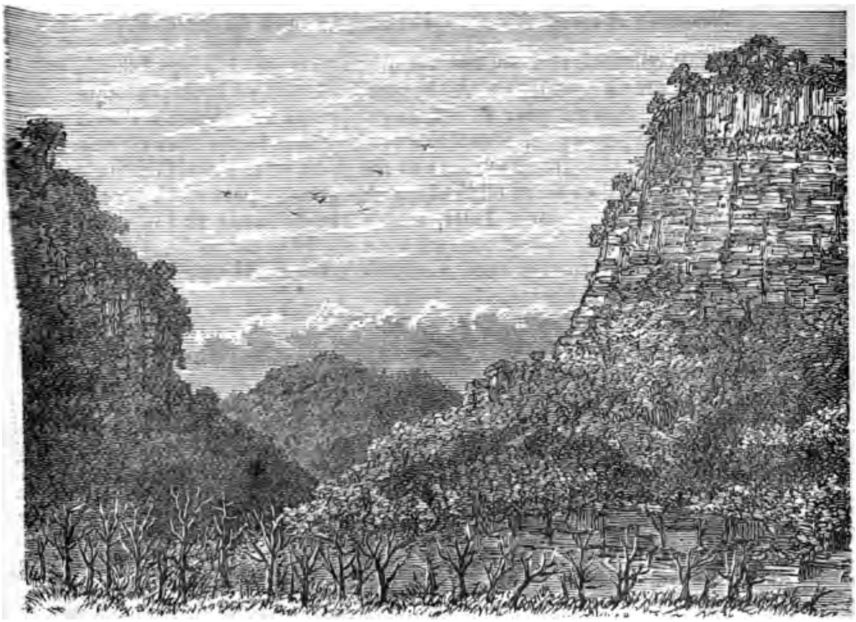
It is highly probable that the rocks of the Wannon and of the Cape Otway district are continuous beneath the intervening Tertiary and Volcanic tract, and also that the Mesozoic rocks extend for a long distance inland beneath the volcanic plains from Colac towards Skipton. Throughout the district cappings of Tertiary sand and gravel overlie these rocks at various elevations up to 900 or 1,000 feet, both on the fall towards the coast and on the slope inland from the eastern and western extensions of the Mount Sabine Range which form the divide of the Otway district between the coast on the south, and the Barwon and Gellibrand Rivers on the north-east and north-west respectively.

The soil of the Cape Otway Mesozoic area is very rich, and supports a dense vegetation of large timber and various scrubs. The country is, however, very broken and intersected by a network of creeks and gullies, with steep ranges between.

From a little to the west of the Gellibrand mouth to Loutit Bay the sea shore is rock-bound, except at Apollo Bay and a few smaller indentations. Very fine specimens of rugged and varied

coast scenery are afforded by the perpendicular cliffs, frequently over 300 feet in height, with the shelving rocks and broken masses at their bases lashed by the "rollers" of the Southern Ocean which here burst ceaselessly upon them. (Fig. 25.)

FIG. 25.—CASTLE ROCK, CUMBERLAND CREEK.
(From a sketch made on the spot by R. Brough Smyth.)



Stratum of dense blue shale 7 feet thick, overlaid by a sandstone cliff 60 feet in height. The Castle Rock exposes a section of coarse-grained yellowish-grey Mesozoic sandstone, upwards of 400 feet in thickness. Dip of beds, E. 5°, S. 26°.

The Mesozoic rocks underlie the tertiaries between Geelong and Queenscliff, as several outcrops of the former are visible, and there is very little doubt that they extend beneath the southern part of Port Phillip, a small portion of their edge being visible on the eastern shore of the bay near the foot of Mount Martha.

The ridge formed by the granite and the Silurian rocks extending from Berwick down between Port Phillip Bay and Western Port, though cut down and covered in places by low-lying tertiaries, probably separates the Mesozoic rocks of the Geelong and Cape Otway area from those of Western Port and South Gippsland. The beds of the two areas are probably continuous with one another beneath the sea, and may possibly be united by a narrow neck beneath the tertiaries of the Carrum and Koo-wee-rup Swamps.

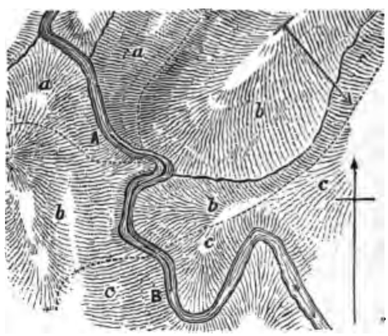
That these rocks do not extend to the north-east shore of Port Phillip is evident from the outcrops of the Silurian rocks at and around Melbourne, and on the St. Kilda beach at Kenny's baths, but it is possible that a tongue of Mesozoic rocks, extending in the direction of Bacchus Marsh, may underlie the great volcanic plains between Williamstown and Station Peak.

Mesozoic Area of Western Port and South Gippsland.

Cape Woolamai, the south-east extremity of Phillip Island, consists of granite, while on the opposite eastern or mainland side the Mesozoic rocks appear in full development at Griffith's Point.

The eastern passage of Western Port Bay thus forms the extreme western limit of this group of rocks at the coast line. From Griffith's Point eastward they form cliffs along the greater part of the coast line as far as Anderson's Inlet, where recent sandy and alluvial deposits cover their line of contact with the Silurian rocks of Cape Liptrap. A line from between Anderson's Inlet and Cape Liptrap over to the north of Foster, at the head of Corner Inlet, would indicate very nearly the boundary between the Silurian rocks on the south and the Mesozoic on the north. The former disappear altogether a short distance east from Foster, while the latter have been proved to a considerable depth below sea-level in bores put down at various places between Foster and Port Albert. From Corner Inlet north-eastward to Tom's Cap, the Mesozoic rocks constitute the prevailing rock-formation of the ranges which slope towards the level Tertiary country bordering the coast.

Fig. 26.—Sketch Plan.



Tyers River.

a Silurian. *b* Mesozoic conglomerate. *c* Mesozoic sandstones, &c.

Sketch Section.

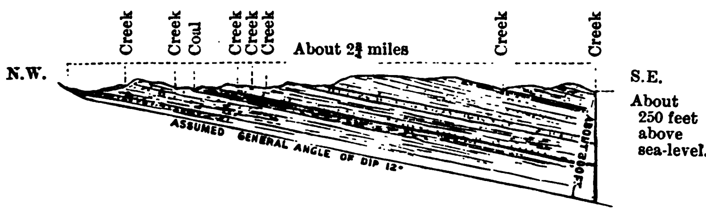
River Bed.

a Silurian. *b* Mesozoic conglomerate. *c* Mesozoic sandstones, &c.

On the north the Tertiary valley of the Koo-wee-rup Swamp and Lang Lang River, extending up from Western Port to the low saddle of the southern spur near Drouin, and thence the valley of the Moe Swamp, down to the junction of the Morwell and La Trobe

Rivers, form the boundary between the Silurian on the north and the Mesozoic rocks on the south. The actual line of contact is completely hidden so far by great accumulations of Tertiary sedimentary and volcanic layers, which occupy the valleys and flank the slopes on either side. From the junction of the Morwell and La Trobe Rivers, for a distance of about 10 miles easterly, the Mesozoic rocks, in the form of a broad patch resting against the slopes of the Silurian rocks, extend back for several miles on the north of the La Trobe valley, and of their northern line of contact with the Silurian rock good sections are visible in the Tyers River and Rintoul's Creek. (Figs. 26 and 27.)

FIG. 27.—APPROXIMATE SECTION OF RINTOUL'S CREEK BEDS.



Upper Silurian. Mesozoic conglomerate. Sandstones and shales. Coal-seam.

The widespread Tertiary and Post-Tertiary deposits of the La Trobe valley, and those continuous thence round the eastern and southern terminal slopes of the Mesozoic tract which lies between the La Trobe and the coast, effectually conceal the eastern limits of the Mesozoic rocks and their line of contact with the Upper Palæozoic rocks of the Macalister, or any formations that may intervene between the two groups. The south-western extension of the Mesozoic rocks visible between Western Port and Anderson's Inlet and the south-eastern extension of those eastward from Corner Inlet pass under the sea, but to what distance cannot be determined.

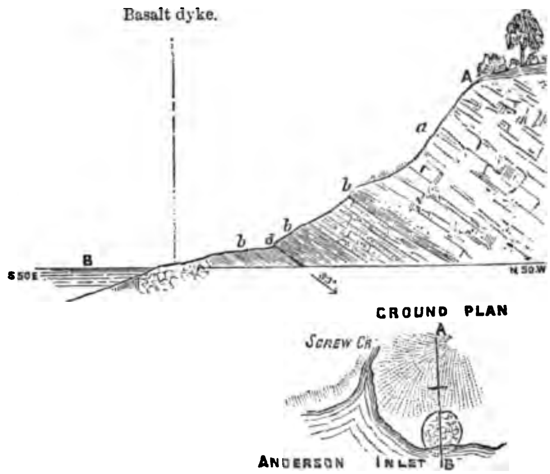
Except a small outcrop of Silurian rocks at Turton's Creek, 10 miles north of Corner Inlet, the entire area within the above-described boundaries consists of Mesozoic rocks more or less overlaid and flanked up to elevations of about 1,000 feet by Tertiary sedimentary deposits and volcanic rocks.

The Western Port and South Gippsland Ranges are similar in physical character and vegetation to those of the Cape Otway district. Their highest elevations, Mount Fatigue—and some points of the Strzlecki Range—slightly exceed 2,000 feet above the sea.

The rocks of Griffith's Point, Kilcunda, and Cape Patterson resemble those of the Otway district. The same descriptions of sandstone and shale occur in the eastern and western Mesozoic

areas. At Griffith's Point there are layers of coarse and fine conglomerate composed of granite detritus, pebbles of quartz, quartzite, &c., and soft earthy breccia-conglomerates made up of water-worn and angular fragments of somewhat hard greenish mudstone. Some of the sandstones between Griffith's Point and

FIG. 28.—SKETCH OF SECTION AT TOWNSEND BLUFF.



a Light-brown jointed sandstone.
b Rubbly grey shales.
c Light-brown fissile sandstone.
d Impure coal-seam 3 inches thick.

Kilcunda afford durable building stones, but, as a rule, the rocks are of a soft felspathic character, much jointed and faulted, the faults being frequently accompanied by basalt dykes, not observed in the Cape Otway country. (Fig. 28.) False bedding and frequent variations of dip and "rolls" in the strata are also noticeable.

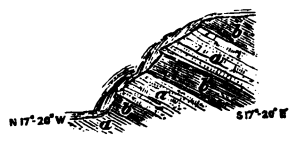
North of the La Trobe valley, along the Tyers River, and in Rintoul's Creek, fine sections occur, showing the contact of the Mesozoic with the Silurian rocks. The lowest beds of the former are coarse thickly-bedded ferruginous and siliceous conglomerates of quartz, quartzite, hard sandstone pebbles or boulders, and sand, derived from the denudation of the Silurian rocks, and, in some places, 100 feet in thickness. These conglomerates become finer in character towards the south, and are overlaid by thick-bedded sandstones, followed by alternating sandstones and shales, which, in different varieties of colour, texture, and hardness, constitute the prevailing rocks of the series, as developed north of the La Trobe and in the South Gippsland Ranges, to the south of that river. The bedding in these tracts is more regular than in the Cape Patterson

or Cape Otway districts, and the dip is nearly constant in a general south-easterly direction at an angle of from 7° to 25°. (Figs. 29, 30, and 31.) In the course of exploration of the Gippsland Mesozoic areas, I found that the south-easterly dip appeared to prevail from the extreme northern edge of the series between the Tyers and Rintoul's Creek to the south-easternmost exposure of the Mesozoic rocks in Bruthen Creek, on the fall towards the coast. This would indicate the very great thickness of over 20,000 feet, assuming an average rate of inclination not exceeding 10°; but it is possible that undulations in the strata may occur, or that the beds become more horizontal between the points where I was able to take the dips, thus necessitating a reduction in the estimate.

Along the Narracan Creek, south from Moe, the strata are sometimes nearly horizontal.

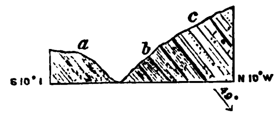
Coal-seams occur in a number of different localities. These will, however, be specially noticed in a subsequent chapter.

FIG. 29.—FALLS ON E. TARWIN.



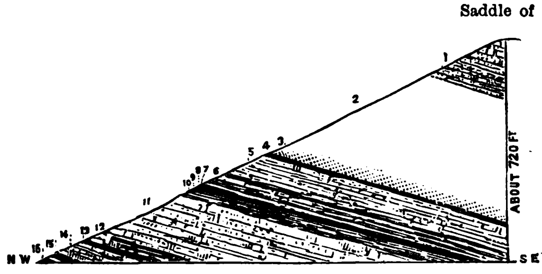
a Fine hard dark-grey sandstone.
b Evenly bedded dark-blue indurated shales. Numerous indistinct plant-impressions.

FIG. 30.—SMALL SECTION IN STOCKYARD CREEK.



a Rubbly sandy shales.
b Extremely hard dark-blue jointed shale, containing carbonate of lime in crevices and four small coal veins from 1 to 2 inches thick.
c Sandstone.

FIG. 31.—SECTION OF ROCKS HEAD OF BRANCH OF TRARALGON CREEK.



1 Soft brown sandstones.
2 Hard fine grey sandstone.
3 Hard fine gritty sandstone.
4 Hard dark-blue shale.
5 Dark-grey fine sandstone.
6 Dark greyish-blue gritty shale and sandstone.
7 Very dark-grey earthy shale.
8 Band 1 foot thick laminar shale, nearly black, with coaly veins.
9 Dark-grey sandy shale.
10 Very hard greyish-blue sandy shales.
11 Hard fine dark-grey jointed sandstone.
12 Alternating hard fine grey gritty sandstones and dark-grey sandy shales.
13 Very finely gritty blackish-grey shale.
14 Hard fine dark-grey jointed sandstone.
15 Very hard finely gritty dark-grey shales.
16 Hard foliated dark-grey sandy shale.

S.E. dips prevail at from 15° to 18°.

Only two species of fossil fauna have yet been discovered in the Victorian Mesozoic rocks, viz., *Unio Dacombi* (McCoy), found in the rocks of the Wannon, and *Unio Murrayi* (McCoy), discovered in a piece of sandstone from near Loutit Bay. Both of these are fresh-water molluscs. Fossil plant-impressions are very numerous, but only a few distinct species have yet been identified. These are figured and described in Decades No. I. and No. II. of Professor McCoy's Prodromus of Victorian Palæontology, and are as follows:—*Zamites* (*Podozamites*) *Barklyi* (McCoy); *Zamites* (*Podozamites*) *ellipticus* (McCoy); *Zamites longifolius* (McCoy); *Tæniopteris Daintreei* (McCoy); and *Pecopteris Australis* (Mor.)—*P. Scarburgensis* (Bean MSS.). These are all characteristically of Mesozoic aspect. The three *Zamites* and the *Pecopteris* are regarded as indicating the Oolitic period of the Mesozoic epoch as that to which the Victorian Carbonaceous rocks are most nearly referable. *Pecopteris*, associated with these in Victoria, has also been found in New South Wales and Tasmania associated with *Glossopteris Browniana*, common in the coal-bearing rocks of those colonies but so far unknown in Victoria.

This has been regarded by eminent authority as evidence in favour of the Mesozoic age of the New South Wales coal-measures; but there is, nevertheless, very strong evidence in support of the belief that the Victorian carbonaceous rocks form a younger group of the Mesozoic series than do the coal-measures of New South Wales, even if the latter are Mesozoic. The Palæontological evidence so far shows that *Pecopteris* is found associated with both *Glossopteris* and *Tæniopteris Daintreei*, but that the two last-named have never been found together, indicating that *Glossopteris* had become extinct before *Tæniopteris Daintreei* came into existence, but that *Pecopteris* outlived the former and flourished contemporaneously with the latter. The late Sir R. Daintree, in his work on the Geology of Queensland, lays considerable stress on the non-association there of *Glossopteris* and *Tæniopteris Daintreei*, the former of which he considers to be indicative of the Palæozoic, and the latter of the Mesozoic age of the rocks in which they are respectively found.

It is very likely that of the numerous species of Mesozoic flora some may have disappeared early in the epoch, while others associated with them continued to flourish through its later periods. The knowledge of how very superficial has been the search made for fossils among the Mesozoic rocks of Victoria tends to guard against too hasty assumptions as to the relations of the Gangamopteris beds of Bacchus Marsh to those containing *Tæniopteris*, *Pecopteris*, &c., of the Wannon, Cape Otway, Western Port, and South Gippsland; or the relation of the whole Victorian Mesozoic series to the Carboniferous rocks of New South Wales. There is not a shadow of a doubt, however, but that the Mesozoic rocks of the Wannon and Cape Otway, Western Port, and South

Gippsland are all of the same geological age, and were formed contemporaneously under very similar conditions, and that between them and the rocks classed as Upper Palæozoic of North Gippsland and the Grampians there is a great stratigraphical break, representing an era of which we have no visible record whatever in the shape of rock-formations. This period seems to have been occupied, as regards the area of the present land surface of Victoria, in the work of denudation. After the completion of the Upper Palæozoic beds, which, as before pointed out, appear to have been formed during long-continued gradual submergence, an opposite movement set in, and the land rose again to as great a height above the sea as it had been previous to the commencement of the Upper Palæozoic layers.

This upward movement of the Victorian land may not have extended to the central eastern portion of Australia, and, if so, we may conjecture that, during the period of emergence here, the northern portions of New South Wales may have continued depressed, or even still sinking. This would imply continued accumulation there but denudation here, and would account for the absence in Victoria, between the two series classed respectively as Upper Palæozoic and Mesozoic, of any formations that can with certainty be referred to the age of the New South Wales coal-measures

The only alternative surmise is, that rocks analogous to the last-mentioned were once deposited in Victoria, and were afterwards removed; but I am more inclined to the belief that while the accumulation of the coal-measures was in progress in New South Wales the Victorian land was simply undergoing denudation. It cannot be said that representatives of the New South Wales coal-measures may not underlie portions of our Mesozoic areas, but so far as can be determined from the evidence of natural sections at their margins, the Mesozoic rocks rest directly on Lower Palæozoic or older igneous rocks, and whatever intermediate formations may exist must lie concealed beneath the Mesozoic rocks in the deeper portions of the basins occupied by them.

Under any circumstances, there must have elapsed, after the close of the Upper Palæozoic period, and prior to the commencement of our Mesozoic formations, a long period during which denuding agencies were busy, and effected great changes on the then rising land surface of the country. When this rising movement had reached its greatest extent the land surface was more elevated than now above the sea. The central mountain mass was still of far greater altitude than now above the contour of the present shore line, as it had not at that time lost the material of which it has been since denuded during Mesozoic and Tertiary times, and, notwithstanding the degradation experienced during the Upper Palæozoic period, still retained an Alpine character, being then very probably many hundreds, if not thousands of feet higher than at the present day.

With re-submergence the deposit of the Mesozoic rocks commenced and continued during long ages of gradual depression, till a flanking deposit had been formed skirting the main mountain system, from the Wannon to Port Phillip, and from Western Port to the Macalister, to a height not less than 2,500 feet above the present sea-level. This does not necessarily imply that every hill or spur of older rocks now under that altitude was then covered. The slopes of the main mountain system were then less denuded than they are now, and a contour line at 2,500 feet above that of the present shore line would have been far nearer to the latter, measuring horizontally, than it is now.

The Silurian rocks and granite of Cape Liptrap and Wilson's Promontory indicate the approximate position of part of the southern margin of the eastern portion of the Mesozoic basin, but it would be impossible without more accurate knowledge of the geology of Tasmania and of the islands in Bass' Straits to form a conjecture as to the boundaries on the south-east and south-west. There is nothing to show what formations were deposited on the north of the Main Divide during the Mesozoic period, unless the conglomerates of the Wild Duck Creek belong thereto. Any extensive deposits that may have existed have been removed, unless some remain concealed beneath the Tertiaries bordering the Murray.

The conditions under which the Mesozoic rocks were deposited do not appear to have been altogether marine, but rather fresh water or brackish, merging into marine. The conglomerates, at the edges of the Mesozoic areas, speak plainly as to the vicinity of the land surface of the period to the localities where we now find them. The character of the fossil flora and of the few fossil fauna yet found tell the same tale. We may regard the Mesozoic rocks as deposits—in previously eroded basins—of sand, silt, mud, &c., brought down from the land surface and arranged by shallow waters, whose currents were fluctuating both in direction and power. The land was in process of slow submergence, and, as it sank, the material derived from its waste continued to be arranged by marine or lacustrine action in layers of varying thickness; sometimes evenly, sometimes unevenly bedded, forming ever-thickening accumulations around the land-margin, near to which larger fragments brought down from the land were rolled and arranged by littoral action in the form of conglomerates.

Intervals occurred during which the conditions were favorable to the accumulation in swamps and low-lying shallow basins of growing or drifted vegetation, subsequently covered by further layers of sand and silt, and altered to the form of coal.

These processes went on until the submergence had attained its limits, and the land began to rise again. From this period commenced a denudation of the beds which had been deposited, and the erosion in them, and in older rocks, of new and deeper hollows or channels, which were destined in their turn to be again partly filled by the accumulations of the Tertiary epoch.

CHAPTER VIII.

Tertiary groups. Oligocene—localities, fossils. Miocene—marine beds, localities, character; lacustrine deposits, quartzites. Fluviatile deposits. Miocene fossils. Older Volcanic Rocks—character, localities.

TERTIARY.

Formations of Tertiary age are very extensively developed in Victoria, occupying nearly one-half the area of the colony; they are geologically divisible with tolerable certainty into three principal groups, viz., Lower Tertiary (Oligocene), Middle Tertiary (Miocene), and Upper Tertiary (Pliocene).

LOWER TERTIARY (OLIGOCENE).

The Victorian Lower Tertiary beds, which the term Oligocene has been employed to designate, really belong to the uppermost portion of the Lower Tertiary group, and appear to occupy an intermediate position between the Eocene and Miocene. Of the Eocene, or Lower Tertiary strata of European and American geology, there appear to be no equivalents exposed in Victoria whatever may be concealed beneath newer formations, and the beds classed as Oligocene are here the oldest known members of the Tertiary series. They are exposed close to the sea-coast in a few localities of very limited extent, of which the best known are as follows:—Portion of the coast between the mouth of the Gellibrand River and Port Campbell; on the coast to the west, and also about a mile inland on the east side of the Aire River a few miles north-west from Cape Otway; in a few places in the Geelong district, and on the east coast of Port Phillip, near Mount Eliza and Mount Martha.

These beds are exposed inland, near the junction of the Grangeburn and Muddy Creeks, a few miles west from Hamilton; also, I understand, near Violet Town, to the north of the Main Divide; and undoubtedly underlie large areas in the western and northern districts. Lithologically, they consist principally of blue or grey clays, sometimes stiff and tenacious, sometimes sandy, with patches composed almost entirely of more or less fragmentary shells, loosely held together by sandy clay. Calcareous septarian nodules are common on the east coast of Port Phillip, in Oligocene clays, which Mr. Selwyn describes as closely resembling the Eocene strata of the Hampshire and London basins. In all places where the beds are exposed, they are rich in fossils, among which are some gigantic forms of Volutes and Cypræa (cowry). The forms

figured and described by Professor McCoy in his Prodromus are as follow :—*Voluta Hannafordi* (McCoy), *V. anti-scalaris* (McCoy), *V. strophodon* (McCoy), *Cypræa* (*Aricia*) *gigas* (McCoy), *C. gastroplax* (McCoy), *C. eximia* (Sow.), C. (*Trivia*) *avellanoides* McCoy), *C. platypyga* (McCoy), *C.* (*Luponia*) *leptorhyncha* (McCoy), *C.* (*Aricia*) *consobrina* (McCoy), *C.* (*Luponia*) *contusa* (McCoy), *Limopsis aurita* (Brocchi sp.), (*L. Belcheri* (Ad. and Reeve sp.). *Pectunculus laticostatus* (Quoy and Gaimard), *Aturia zic-zac* (Sow. sp.), var. *Australis* (McCoy), *Cucullæa Corioensis* (McCoy), *Pecten Yahlensis* (Woods), var. *semi-lævis* (McCoy), *Waldheimia macropora* (McCoy), *Spondylus pseudo-radula* (McCoy), &c.

Some of these fossils, or closely-allied species, are not confined to the Oligocene, but are found also in the Miocene, and even in the Pliocene beds.

MIDDLE TERTIARY (MIOCENE).

Formations of this age are extensively developed in Victoria. They comprise deposits due to marine, lacustrine, and fluviatile agencies, and also the rocks of igneous origin, classed as Older Volcanic, which appear to be the youngest of the group, and to form the division between beds of Middle Tertiary or Miocene, and those of Upper Tertiary or Pliocene age.

In proportion to the actual extent of the tracts underlaid by them, the Miocene strata, of marine origin, appear as the surface formation of but very small areas, and are only exposed on the sea coast, or on the slopes towards rivers and creeks, where the newer overlying formations have been cut through and denuded; but their presence has been proved by bores and shafts, beneath great tracts of which the surface formations are Upper Tertiary or Newer Volcanic.

Rocks of Miocene age form the cliffs along the sea-coast, from the Glenelg to the Gellibrand River, with the exception of a few breaks between Portland and Warrnambool, where overlying newer formations, occupying depressions in the Miocene beds, are found at the sea-level. The coast scenery between the Gellibrand and Warrnambool is of a most picturesque character. The cliffs are about 200 feet in height, generally perpendicular, and jut out into frequent headlands. (Fig. 32.)

The encroaching action of littoral denudation is well exemplified by the number of islets standing at short distances out at sea. These are of the same height and composed of the same rock-bands as the main cliffs, and are evidently portions which have been left unremoved during the denudation of the mass.

Miocene strata occupy a small area on either side of the Aire River, north-west from Cape Otway. Eastward from Loutit Bay they are again found, forming the cliffs along the coast.

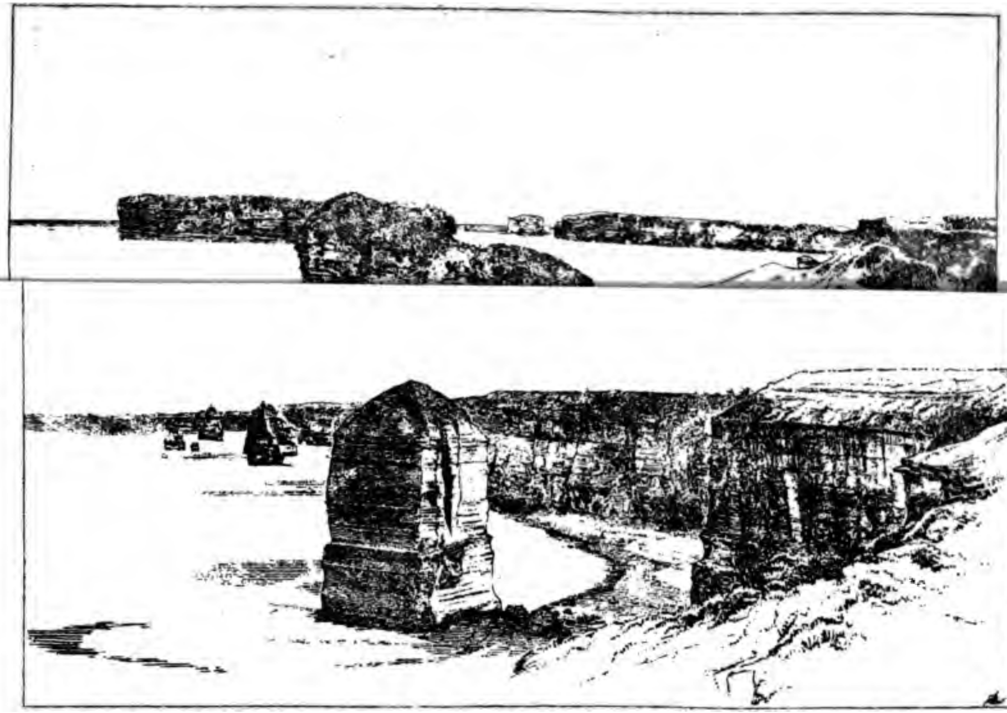


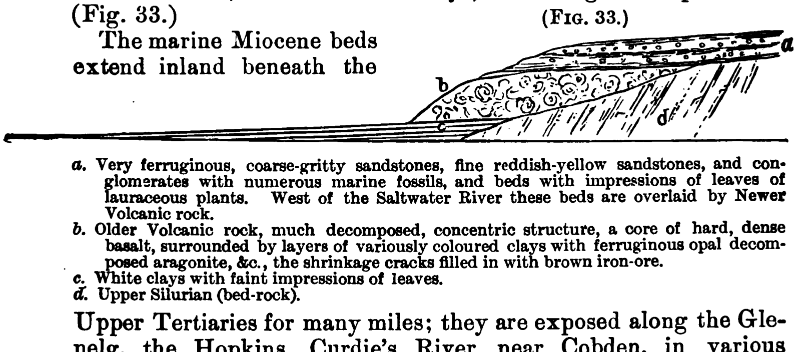
Fig. No. 32.—CLIFFS AND ISLETS WEST OF PRINCETOWN, CAPE OTWAY DISTRICT.

The rocks consist of whitish and yellowish-brown sandy calcareous layers, sandy ferruginous layers, yellowish sandy limestones, coralline limestones; composed almost entirely of fragmentary shells and polyzoa, and calcareous clays. Near the mouth of the Gellibrand is a bed of conglomerate resting upon and composed of rolled fragments of the Oligocene clays which occur there. There are also some black clay beds, containing leaf impressions, east of the Gellibrand, near where the Miocene beds thin out on the Mesozoic rocks. Similar clays occur westward of the Aire River, near Cape Otway, and at Point Addis. The cliffs on the coast near Spring Creek, south from Geelong, have been described in a report and geological map of that district by the late Sir R. Daintree. The thickness exposed is about 300 feet, of which the upper portion, of about 100 feet, consists chiefly of yellow sandy limestone, composed principally of polyzoa and fragments of echini spines. The principal characteristic fossils of these upper beds are *Cellepora Gambierensis*, *Spatangus Forbesi*, and *Terebratula Compta*. Next in descending order come about 150 feet of yellow and brown sandy clays, containing a prevalence of bivalve shells, principally *Pectunculus laticostatus* and pectens. Below these are Oligocene beds, containing principally univalve shells.

Some of the limestones are very hard and compact, and blocks may be obtained near Geelong and at Maude, on the Moorabool, showing, when polished, handsome shell markings.

Near Melbourne, the Miocene beds, passing under the Older Volcanic rocks, consist of white clays, containing leaf impressions. (Fig. 33.)

(Fig. 33.)



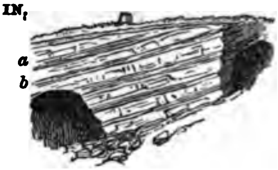
a. Very ferruginous, coarse-gritty sandstones, fine reddish-yellow sandstones, and conglomerates with numerous marine fossils, and beds with impressions of leaves of lauraceous plants. West of the Saltwater River these beds are overlaid by Newer Volcanic rock.
b. Older Volcanic rock, much decomposed, concentric structure, a core of hard, dense basalt, surrounded by layers of variously coloured clays with ferruginous opal decomposed aragonite, &c., the shrinkage cracks filled in with brown iron-ore.
c. White clays with faint impressions of leaves.
d. Upper Silurian (bed-rock).

The marine Miocene beds extend inland beneath the Upper Tertiaries for many miles; they are exposed along the Glenelg, the Hopkins, Curdie's River near Cobden, in various localities north of the Cape Otway Ranges, and for long distances up the Moorabool and Leigh Rivers.

There is no doubt that they underlie the greater portion of the western plains. At Mount Mary, an extinct Newer Volcanic crater, near the Werribee, ejected blocks of rock containing Miocene fossils occur among the volcanic ash and other materials of which the hill is composed, showing that the Miocene beds underlie the

plains between Melbourne and Station Peak. They also occur along the Murray, and have recently been proved, during boring operations in search of water, to exist beneath the great plains of the North-Western district. In Gippsland they appear to underlie the low country near the coast from Port Albert to the Snowy River, though only exposed in a few localities, as at Woodside, Merriman's Creek, Boggy Creek near Sale, the Mitchell River from Iguana Creek to the Gippsland Lakes, and on the coast eastward from there. (Fig. 34.)

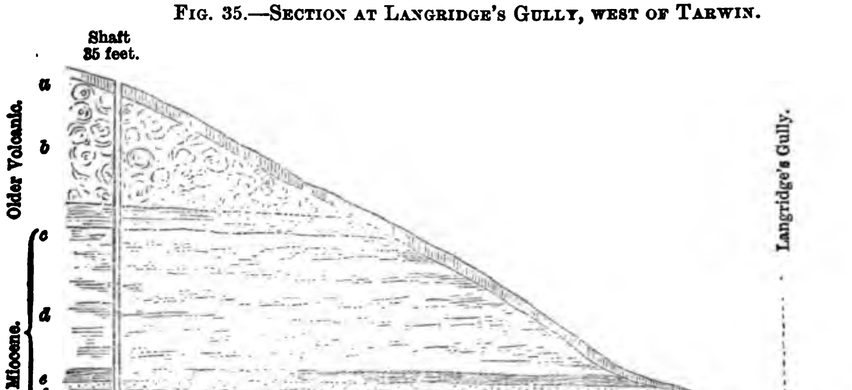
FIG. 34.—SECTION OF LOWER TERTIARY BEDS NEAR SALE.—EXCAVATION FOR LIMESTONE IN.



a Hard limestone.
b Soft clay-bands.

Many of our widespread ferruginous gravels and conglomerates appear to be of Miocene age, and to be the results of littoral action during that period. It may, however, be taken as an established fact that no marine Miocene strata have been yet found in this colony at an elevation exceeding 700 feet above the level of the sea. It has been remarked that no marine Miocene beds are to be met with on the coast of New South Wales.

FIG. 35.—SECTION AT LANGRIDGE'S GULLY, WEST OF TARWIN.



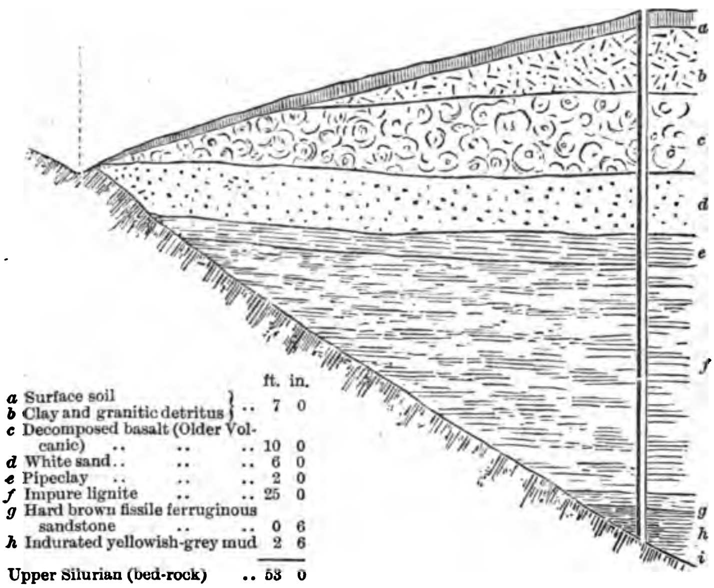
a Surface soil.
b Decomposed dark-grey basalt, 14 feet 6 inches.
c Pipeclay, 2 feet.
d Impure finely laminated lignite, 15 feet.
e Hard brown fissile sandstone, containing fossils (serrated leaves) and conforming in its undulations to the subjacent deposits, 6 inches.
f Sandy drift, 1 foot.
g Well rounded auriferous quartz-gravel, 2 feet.
h Upper Silurian (bed-rock).

The Miocene beds apparently due to lacustrine action consist chiefly of clays and lignites, filling basins in older rocks. Such a

basin exists at Morrison's diggings on the Moorabool, near Meredith, where, in some places, the Miocene deposit forms a "false bottom," on which rest auriferous gravels of Pliocene age. The extent of this basin is not well known, but its outlet to the sea was unmistakably about where the township of Meredith now stands. The great lignite deposit at Lal Lal is possibly of this age, and there is no doubt as to the lignites of McKirley's Creek and the Tarwin in Gippsland being so, because they are overlaid by Older Volcanic rocks. (Figs. 35 and 36.)

Ferruginous beds, containing fossil leaves, occur near Bacchus Marsh, and beneath the basalt of the Dargo High Plains. In many localities throughout the country are exceedingly hard quartzites, which appear to be fine siliceous silt, or possibly

FIG. 36.—SECTION AT SCALP CREEK, EAST OF TARWIN RIVER.

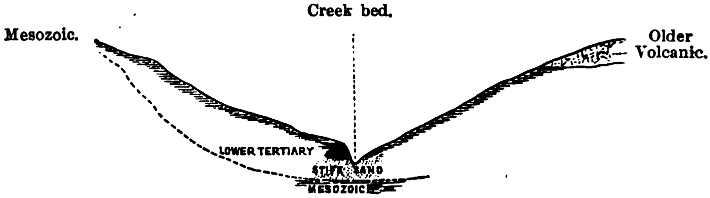


infusorial earth, cemented and indurated by siliceous infiltrations. They often pass into siliceous conglomerates, containing well-rounded quartz pebbles, which occasionally show signs of partial blending with the siliceous matrix. Hydrothermal action has been suggested as a probable cause in the production of these quartzites, and it is readily conceivable that the percolation by heated waters or steam, of fine sand and gravel or infusorial earth, would result in the development of such rocks as the quartzites referred to. Wherever the relative positions have been observed, these

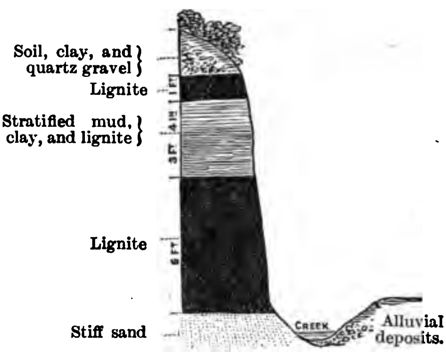
quartzites have been found to be clearly antecedent to the Older Volcanic rocks, and apparently synchronous with the marine Miocene beds, and have on that account been classified as of Miocene age.

The Miocene formations due to fluviatile action are principally developed in Gippsland, where there are deposits of sand, gravel, and conglomerate capped by older basalt occurring in isolated patches, evidently once connected deposits, but now separated from one another by the more deeply eroded river-valleys of the

FIG. 37.—LIGNITE, ETC., IN NORTH BRANCH OF TARWIN RIVER.

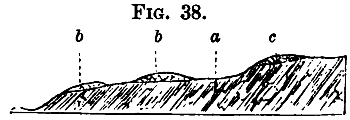


present era which have cut through and to a great extent removed the Older Tertiary drift deposits. (Fig. 37.)



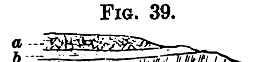
Some of these lava-capped vestiges are found at elevations up to 5,000 feet above the sea, and constitute portions of the present Main Divide. The gravels, sands, and clays covered by Older Volcanic rocks, which occur at the Dargo and Bogong High Plains are the best examples of these Miocene patches at high elevations. There are many other smaller outliers, as at the top of Mount Useful, Connor's Plain on the Main Divide, between the Macalister and Goulburn drainage areas, Mount Lookout, between the Aberfeldy and the Thomson, &c. (Figs. 38 to 41.)

FIG. 38.



a Silurian. *b* Older Volcanic. *c* Siliceous rock.

FIG. 39.

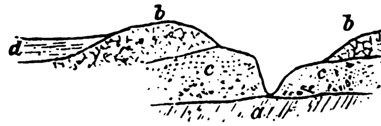


a Silurian. *b* Older Volcanic. *c* Siliceous rocks.

Gravels, siliceous and ferruginous conglomerates, clays, sands, and impure lignites of

fluviatile and partly lacustrine origin, and overlaid by Older Volcanic rocks, are found in country of medium elevation round the flanks of the main mountain mass at Glenmaggie, Seaton, Haunted Hill, Tanjil, Russell's Creek, and Neerim, in Gippsland, Berwick, Hoddle's Creek, Kangaroo Ground, and other localities to the westward.

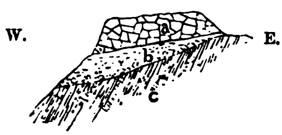
FIG. 40.



a Silurian. *b* Older Volcanic. *c* Siliceous rock and conglomerate. *d* Upper Tertiary.

Near Steiglitz certain widespread gravels and ferruginous conglomerates are traceable down from the flanks of the ranges till they pass into marine Miocene beds, thus showing themselves to be of Miocene date. I believe that many of the gold drifts hitherto regarded as Pliocene may eventually have to be classified as Miocene.

FIG. 41.
Sketch Section of Connor's Plain.



a Older Volcanic. *b* Siliceous conglomerates, clays, and gravels (Miocene). *c* Silurian.

The following are the principal Miocene fossils figured and described by Professor McCoy in his Prodromus of Victorian Palæontology :—

Mammalia.—*Squalodon Wilkinsoni* (McCoy); *Cetotolites* (ear-bones of whales) *Leggei* (McCoy); *Cetotolites Pricei* (McCoy); *Cetotolites Nelsoni* (McCoy).

Fishes.—*Carcharodon angustidens* (Ag.); *Carcharodon megalodon* (Ag.). Radiata.—*Tethya Newberyi* (McCoy); *Graphularia Robinæ* (McCoy); *Clypeaster Gippslandicus* (McCoy); *Lovenia Forbesi* (McCoy); *Monostychia Australis* (Laube); var. *Loveni* (Dunc.).

Mollusca.— *Voluta anti-cingulata* (McCoy) and *macroptera* (McCoy); *Trigonia acuticostata* (McCoy); *T. Howitti* (McCoy); *T. semi-undulata* (McCoy); *Aturia zic-zac* (var. *Australis*) (McCoy); *Pleurotomaria Tertiaria* (McCoy); *Haliotis ovinoides* (McCoy); *H. Mooraboolensis* (McCoy); *Cucullæa Corioensis* (McCoy); *Cypræa* (*Aricia*) *platyrhyncha* (McCoy); *Pecten Yahlensis* (*var. semi-lævis*) (McCoy); *Spondylus gæderopoides* (McCoy); *Spondylus pseudo-radula* (McCoy); *Waldheimia Corioensis* (McCoy); *W. macropora* (McCoy); *Cardium pseudo-magnum* (McCoy); *Cardium* (*Protocardium*) *anti-semigranulatum* (McCoy); *Hinnites Corioensis* (McCoy).

Plants. — *Cinnamomum polymorphoides* (McCoy); *Laurus Werribeensis* (McCoy); *Salisburia Murrayi* (McCoy).

Among a number of species of fossil fruit described and figured by Baron von Mueller, and found in gold drifts classed as Pliocene,

the following species have been also found in the drifts of apparently Miocene age at Tanjil:—*Spondylostrobus Smythii*, *Phymatocaryon Mackayi*, *Celyphina McCoyi*, *Conchotheca turgida*, and *Platycoila Sullivani*. Another species, *Plesiocapparis prisca*, has been obtained in auriferous gravels of Miocene age beneath Older Volcanic layers at Hoddle's Creek, Upper Yarra.

Older Volcanic Rocks.

The different Volcanic rocks of the Tertiary period are so associated with the sedimentary layers that, in order to convey a clear idea of their relations, it is advisable to describe them in their order of sequence with the latter, instead of in a special chapter by themselves.

The Older Volcanic rocks are the latest products, and mark distinctly the close, of the Middle Tertiary or Miocene era. There do occur, occasionally, thin volcanic layers, interstratified with the Miocene sedimentary beds, showing that vulcanicity was not altogether dormant during the formation of the latter, but the greatest volcanic activity evidently took place at the close of the period. Where undecomposed, the Older Volcanic basalts are usually dark, dense, and solid, of a polygonally jointed and sometimes distinctly columnar structure, and composed chiefly of augite, labradorite, olivine, and specular iron. They are, however as a rule, either wholly or partly decomposed. In the former condition, they consist of red, yellow, purple, brown, and nearly white amygdaloidal clays, containing hard lumps of less decomposed rock showing concentric structure; in the partly decomposed state the rock exhibits in sections the appearance of a conglomerate of such concentric masses in a clay matrix.

In every locality throughout the colony where the Older Volcanic rocks are at the surface the soil immediately resting on or derived from them is of great fertility and of exceptional value for agriculture. In the Neerim, Brandy Creek, and other districts in Gippsland, the natural vegetation growing on such soil is of a most luxuriant sub-tropical character, forming a serious impediment to the labours of the selectors, who, during late years, have eagerly taken up every available acre of such land.

The sources whence the Older Volcanic lava streams issued have not yet been distinctly recognised; no well-marked points of eruption such as are common in the Newer Volcanic districts have been observed, and it would appear that the original volcanic cones have been entirely removed by subsequent denudation, so that it would only be in what are now narrow or small pipe-shaped dykes, easily passed over unobserved, and probably far distant from where the Older Volcanic rocks remain in considerable area, that we might look for the vents whence the flows were poured forth. The original extent covered by Older Volcanic rocks was once very

much greater than now. The areas we now see occupied by them are for the most part disconnected vestiges of what were once long, continuous, and frequently also widespread sheets, which have been cut into and through by subsequent denuding agencies, so that, in many places, the Older Volcanic rocks, which, at the time they were poured forth as lavas, flowed down and partly filled in the valleys of the period, are now the cappings of ranges, owing to the erosion of still deeper valleys on either side. Enough still remains to enable some conjectures to be formed as to the areas once occupied by the Older Volcanic rocks; the conclusions arrived at will, however, be better understood after the existing Older Volcanic areas have been described, and will, therefore, be included in the general sketch history of the Tertiary period given in a subsequent chapter.

Older Volcanic rock occurs in patches, filling hollows in Miocene and other older formations in the neighbourhood of the Moorabool River, near Maude, and in one place as an intercalated band between marine Miocene beds; it also constitutes a considerable area of the Bellarine district, south of Geelong harbor.

From between Ballan and Blackwood down to near Bacchus Marsh the Older Volcanic rock occurs in a number of localities, especially on the Pentland Hills, where some of the undecomposed basalt of this age is highly magnetic.

From near Romsey down to Melbourne there are several exposures of this rock in beds and banks of creeks that have cut their way down to it through newer overlying formations. Near Flemington is an area consisting of Older Volcanic decomposed basalt, which may be seen in natural section on the bank of the Saltwater River, passing under Upper Tertiary ferruginous deposits, capped with basalt of Newer Volcanic age. From Hoddle's Creek, a branch of the Upper Yarra, a series of disconnected patches, in some places underlaid by auriferous gravels, are traceable in the direction of Melbourne, as far as Lilydale. Other patches occur between the Yarra and the Plenty, near the Kangaroo Ground. This formation occurs again at Berwick and Cranbourne, and has been proved, by boring operations, to exist beneath some 200 feet of Upper Tertiary deposits near Frankston. Cape Schanck and portion of the country between Western Port and Port Phillip, also Phillip Island and French Island in Western Port Bay, consist of Older Volcanic rocks in places undecomposed, and consisting of hard dark dense basalt. This rock, more or less decomposed, occupies a strip extending from Griffith's Point along the east coast of Western Port Bay, and I believe this to be portion of and continuous with the French Island and Phillip Island layers, and to be united beneath the Newer Tertiaries with the Older Volcanic rocks which occupy so extensive a tract in the Neerim and Buln Buln district.

Large and small strips and patches are found between the Tanjil and La Trobe Rivers and in various portions of South Gippsland. A well-defined lead, covered by 200 feet of older basalt, has been proved to trend, from between Walhalla and Mount Baw Baw, southward to the level country near Toongabbie. Very extensive sheets of older basalt probably underlie parts of the low Upper Tertiary country of Gippsland, as it may be seen sloping from the hilly country, and passing under the plains at Haunted Hill, Toongabbie, Seaton, Glenmaggie, and also at many places on the south side of the La Trobe Valley. The basalt of the Dargo and Bogong High Plains has been classed as Older Volcanic, because it immediately overlies sedimentary beds containing Miocene flora, and its lithological character also justifies this classification. Here we find many hundreds of feet in thickness of lava, for the most part undecomposed, and often highly magnetic, showing, in many places, columnar structure in a marked degree. Portions of the plains where the rock is bare resemble a pavement of five-sided blocks ; while, on the slopes below the escarped edges of the plains, acres in extent are covered with pentagonal columns of basalt like logs confusedly heaped together.

Similar outliers of basalt, but of less extent, occur at Connor's Plain and Fullarton's Spring Hill, both points on the Main Divide between the Gippsland and Murray River basins, also to the southward at Mount Useful and Mount Lookout, the ranges between the Aberfeldy and the Thomson, and between the Thomson and the Tyers Rivers. A very small outlier occurs on the east slope of Mount Matlock, and other patches are found on the Southern Spur, between the sources of the Yarra and those of the La Trobe.

The general evidence obtained from observation of the Older Volcanic areas points irresistibly to the conclusion that they are remnants of extensive lava-flows which poured down the valleys of the Miocene period, partially filling in the basins and covering the sedimentary deposits in them, and also spreading in wide layers over the beds of the estuaries and inlets. Subsequent denudation has cut through and destroyed the continuity of these lava-flows ; new channels have been excavated to lower levels than the ancient ones, which they filled, and fresh accumulations have in many places overspread them.

CHAPTER IX.

Upper Tertiary Formations. Marine Beds. Fluviatile Deposits. Fossils. Vegetable, Marine, and Land Animals. Newer Volcanic Rocks. Areas occupied. Points of Eruption. Post Tertiary Deposits. Sand-dunes.

UPPER TERTIARY.

Under this head are included all aqueous deposits, marine or fluviatile, and associated lava-flows, younger than the Older Volcanic, and older than the Newest Volcanic rocks, which latter are taken as the latest products of the Tertiary period; deposits newer than they being regarded as Post Tertiary and recent.

On the geological sketch-map all the aqueously deposited formations, newer than Middle Tertiary, are distinguished by one colour, as Upper and Post Tertiary; but on the detailed geological maps are indicated a number of subdivisions into Older Pliocene, Newer Pliocene, Post Pliocene, and Alluvial.

In some of the maps the reference of deposits to European equivalents has been omitted, and the formations have been classed in their order of sequence as "oldest" and "older" gold drift, "recent" and "most recent," or in progress. In many places the lines of subdivision are clearly indicated by lava-flows, by the character of the deposits themselves, and by the physical configuration of the country, but in others no such lines of demarcation exist. The classification of the deposits is the more difficult on account of the scarcity of fossils whereby the true positions in the Newer Tertiary series of any particular beds could be ascertained.

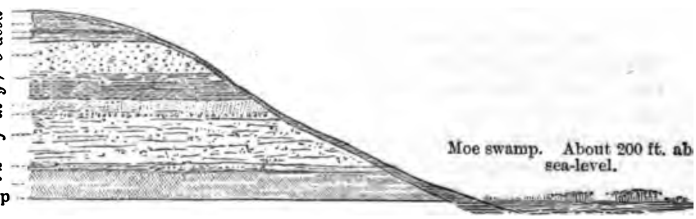
As in the case of the Miocene or Middle Tertiary formations, we have, among those of the Upper Tertiary series, beds deposited by marine agency, and deposits clearly due to fluviatile action.

The marine Upper Tertiary deposits consist principally of fine and coarse ferruginous sandy beds, in some cases hard, in other soft and friable, gravels, conglomerates, sands, clays, and mud shales.

They are found resting on the Older Volcanic, the Miocene, beds, or the Mesozoic and Palæozoic rocks, from the coast-line to the flanks of the mountain systems, and up all the main valleys, to elevations within 1,000 feet above sea-level; they also lie on the low spurs of the northern slopes of the ranges on the fall towards the Murray. They have been much denuded during Post Tertiary times, and are, consequently, wanting in many places, while in others they are covered by newer accumulations or the Newer Volcanic lava-flows.

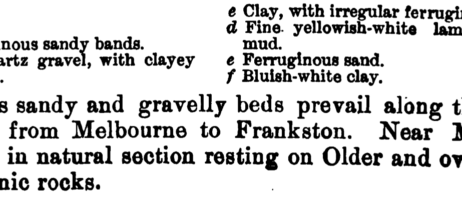
A great extent of country near the western boundary of the colony, along the Glenelg River, along the coast from the Glenelg to Portland, and from Warrnambool to the Gellibrand, consists of Upper Tertiary sandy deposits resting on the Miocene beds and Mesozoic rocks, and passing under the Newer Volcanic rocks at the edges of the latter. Similar sandy and gravelly deposits in extensive areas, or large and small outliers, flank on all sides the Mesozoic ranges of the Cape Otway district, and of Western Port and South Gippsland. (Figs. 42 and 43.)

FIG. 42.—SECTION OF PLIOCENE TERTIARY BEDS AT WESTBURY.



a Surface soil.
b White and yellow clay with red seams.
c Brick-red indurated ferruginous clay.
d Yellow and red clay.
e Coarse granitic detritus and brown ferruginous sand, very micaceous, with a little clay.
f Laminar brown sand, ferruginous and micaceous, with white and brown clay bands and hard ferruginous seams.
g Evenly bedded, horizontally laminar clay, greyish-white and light-brown, finely micaceous, resembling some decomposed Silurian shales in character.
h Fine greyish-white clayey sand.
i Variegated light-brown and whitish clay, containing quartz, pebbles, and sand.
j Granitic detritus and clay, variegated red, brown, and whitish.
k Variegated clay, occasionally sandy, white, light-brown, bluish, and reddish.
l Consolidated sand and clay, brown and white streaked.

FIG. 43.—SECTION OF UPPER TERTIARY (OLDER PLIOCENE) BEDS IN ROSEDALE CUTTING (MAIN ROAD).



a Surface soil.
b Clay.
c Stratified ferruginous sandy bands.
d Ferruginous quartz gravel, with clayey and sandy layers.
e Clay, with irregular ferruginous bands.
d Fine yellowish-white laminar clay or mud.
e Ferruginous sand.
f Bluish-white clay.

Ferruginous sandy and gravelly beds prevail along the east of Port Phillip, from Melbourne to Frankston. Near Melbourne they are seen in natural section resting on Older and overlaid by Newer Volcanic rocks.

On the northern fall from the Main Divide, and passing under the Post Tertiary deposits of the plains, are gravels and conglomerates, some of which are too widely spread to be due to other than littoral marine action; among these are richly auriferous gravels and conglomerates.

Fresh-water limestones of Pliocene age occur near Geelong, and in other localities.

The Pliocene deposits due to fluviatile action appear to be younger than some of those of the same period which are of marine origin, and to be among the latest products of the epoch, though there is no doubt that the processes to which their formation is immediately due began very early in, if not previously to, the Tertiary era. These ancient river deposits consist of gravels, conglomerates, sands, and clays, occupying channels in the older rocks, and where they are worked for their associated gold are known as deep leads. As followed downwards towards the sea or towards the Murray Valley, they merge into wide-spread marine deposits, the margins of which mark the approximate position of the sea-board of the time when the lead channels were occupied by rivers. The gravels in these old river-beds are covered by thicknesses of from a few to several hundred feet of newer aqueous deposits, or layers of Newer Volcanic rock (basalt).

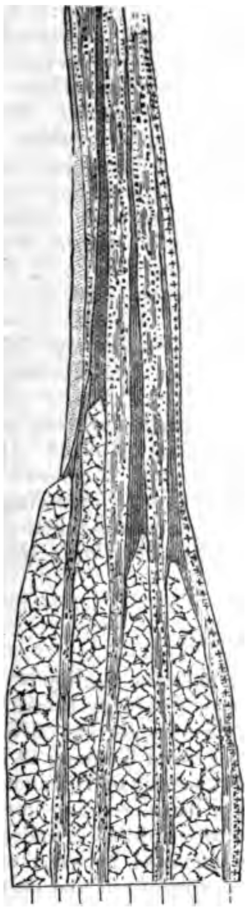


FIG. 44.—SKETCH ILLUSTRATING THE MODE IN WHICH SEDIMENTARY DEPOSITS ACCUMULATED BEHIND THE DAM FORMED BY EACH SUCCESSIVE LAVA-FLOW.

a First rock. *b* Clay, &c. *c* Second rock. *d* Clay, &c. *e* Third rock. *f* Clay, &c. *g* Fourth rock. *h* Gutter-bed.

Where there are two or more distinct layers of basalt, there are generally found interbedded between them deposits of clay, sand, gravel, and occasionally lignite of varying thickness. (Fig. 44.)

The deep leads of Ballarat, Haddon, and Daylesford are types of the lava-covered Upper Tertiary fluviatile deposits, while the leads of Chiltern, Huntly, and Dunolly are instances of those covered only by newer sedimentary accumulations.

Near Amherst is a deposit (probably lacustrine) of infusorial earth, seventeen feet in thickness, resting on basalt. It is composed entirely of the siliceous skeletons of microscopic animalculæ (*Diatomaceæ*) and is largely used in the manufacture of dynamite. Further remarks on the Pliocene gravels will be found in connexion with the subject of auriferous alluvial deposits in a subsequent chapter.

Among plant remains found in Upper Tertiary deposits are:—*Eucalyptus Pluti* (McCoy), and the various species of fossil fruit figured and described by Baron von Mueller, namely:—*Spondylostrobus Smythii, Phymatocaryon Mackayi, Trematocaryon McLellani, Rhytidotheca Lynchii, Plesiocapparis prisca, Celyphina McCoyi, Odontocaryon Macgregorii, Conchotheca rotundata, Rhytidotheca pleioclinis, Penteune Clarkei, Penteuue brachyclinis, Penteune trachyclinis, Dieune pluriovulata, Platycoila Sullivani, Phymatocaryon angulare, Conchotheca turgida.*

The principal marine Pliocene fossils figured and described by Professor McCoy are:—Mollusca.—*Trigonia acuticostata* (McCoy), *Haliotis Nævosoides* (McCoy), *Cerithium Flemingtonensis* (McCoy), *Waldheimia macropora* (McCoy), *Ditrupa Wormbetensis* (McCoy), *Lepralia Stawellensis* (McCoy), *Micula Marthæ* (McCoy), *Tellina Krausei* (McCoy). Mammalia.—*Arctocephalus Williamsi* (McCoy), and *Physetodon Bayleyi* (McCoy).

Among land animals of Upper Tertiary and Post Tertiary times are *Diprotodon longiceps* (McCoy), *D. Australis* (Owen), *Phascolomys pliocenus* (McCoy), *Thylacoleo carnifex* (Owen), *Macropus Titan* (Owen), *Procoptodon Goliah* (Owen), *Nototherium Sarcophilus ursinus* (Harris), *Dasyurus affinis* (McCoy), *Hypsiprymnus trisulcatus* (McCoy), *Canis dingo*, and others. Some of these appear to have become extinct at comparatively very recent periods, while one, the *Canis dingo*, or native dog, is still in existence.

Newer Volcanic.

The basalts, or anamesite and dolerite lavas, familiarly known as "bluestone," occur in sheets or strips of varying breadth overlying a large extent of the central western portion of Victoria. The great plains of the western district, from Geelong to Hamilton and from Colac to Ararat, are nearly wholly of volcanic origin, while most of the ancient river-beds or leads trending north and south from the Main Divide are more or less filled in and covered by lava flows which, though often confined between elevated Silurian ridges near the hilly country, spread out and unite with the wide sheets that constitute the plains. To the northward of Ballarat, portion of the Main Divide itself is of volcanic formation, and a wide sheet extending to the north, and finally disappearing under the Post Tertiary deposits of the Loddon, covers the

system of deep leads of Creswick, Clunes, and Daylesford, on their trend towards the Murray. At Ballarat there are four and in other places two or three distinct layers of basalt covering the leads.

The lowest overlie the deepest parts of the gutters, and the next in succession spread more widely till, as may now be seen, the uppermost lava-flow forms a wide sheet, covering not only the old rivers and their tributaries, but also most of the lower ridges of Silurian rock which separate them.

Throughout all the Newer Volcanic areas are found the points of eruption whence the lava streams issued, mammaloid or conical hills in many of which well formed crater-basins still exist, while in others the crateriform shape is still distinguishable though the basin has been obliterated. Many of these extinct craters are now occupied by lakes or lagoons, as Tower Hill, near Warrnambool, which has an insular peak rising from the centre of the lake; Mount Eels, and other crater basins in the Western District, and Mount Mercer, south from Buninyong. Mounts Buninyong, Warrenheip, Pisgah, Franklin, and numerous other volcanic hills in the Ballarat, Creswick, Daylesford, and other districts, are familiar instances of points of eruption where the outlines of the craters are still discernible.

Around nearly all such points are scoriaceous lavas and volcanic ashes, among which are frequently found ejected masses of older rocks, from mere dust up to several tons in weight.

For instance, in the volcanic ash of the Anakies, near Geelong, are found ejected blocks of granite. At Buninyong and Hardie's Hill, to the south thereof, are ash beds, composed principally of large and small fragments of slate and schist. In some places, as on the Werribee Plains, near Mount Mary, the ash beds present a stratified appearance, as though their materials had fallen into and had been arranged by water. It is probable that this may have been the case, but there is no evidence of any very considerable submergence since, as, had such taken place, very few, if any, of the volcanic hills, composed as they are of loose incoherent materials, would have preserved their form as we now see them. It is probable, however, as suggested by Mr. Selwyn, that some of them formed low islands in the Tertiary seas.

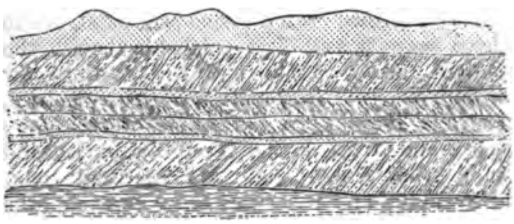
Post Tertiary.

The Post Tertiary deposits, or those which have been formed since the Newer Volcanic lava flows, consist of gravels, clays, sands, mud, loam, &c., and sometimes form very extensive tracts of good alluvial soil.

They rest directly on the Palæozoic or the Mesozoic rocks, or on Tertiary beds and volcanic layers, as the case may be.

The surface deposits of the level plains around Sale, in Gippsland, and those bordering the Murray River, belong to this class, and are not unfrequently to be found almost undistinguishably blended with those in actual process of formation. The sand dunes and sand rocks of the isthmus between Corner and Shallow Inlets, Cape Otway, and other parts of the coast-line, are of Post Tertiary age, some of them being of comparatively ancient and others of quite recent date or even now in process of formation.

FIG. 45.—SKETCH ILLUSTRATING STRATIFICATION OF SAND-ROCK.



Some of these consolidated sand-rocks show remarkable bedding, due evidently to the fact of their materials having been transported and arranged by the action of wind. At Warrnambool the sand-rocks present a regular schistose appearance, with a strong dip inland, as though they had been uptilted, but in reality due to their having been formed by winds which blew the sand back from the coast-line and deposited it in layers sloping at an angle of about 30° on the inland slopes. (Fig. 45.)

Many of the gold drifts are of Post Tertiary age, and consist of freshly denuded fragments from the Silurian and other rocks, or the re-distributed materials of Tertiary gravels and other formations in their neighbourhood that may have been subjected to denudation. A few deposits of inferior lignite are associated with some of the Post Tertiary clays in creek and river flats.

CHAPTER X.

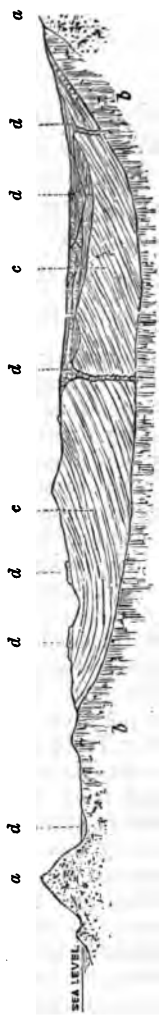
Geological History during Tertiary Epoch. Erosion of Mesozoic Rocks. Oligocene Deposits. Miocene—Fauna. Geographical Conditions. Miocene — Rivers, Lakes. Flora. Volcanic Action. Pliocene Deposits. Marine—Fluviatile. Newer Volcanic Lava-flows. Basin of Yarra. Post Tertiary Action and Deposits. Sand-dunes. Fauna. General Concluding Remarks.

In drawing conclusions as to the geological history of this country during the Tertiary epoch, the first fact to be observed is the enormous denudation during Upper Mesozoic and Lower Tertiary times, to which all pre-existing formations must have been subjected before even the lowest Tertiary deposits found in Victoria commenced to be laid down. The Mesozoic rocks especially appear to have been entirely removed from large areas, and deep channels to have been eroded along their lines of junction with other rocks. The sections obtainable in the Western Port and South Gippsland districts show this beyond a doubt, as we find that the great depression connecting Western Port with the Gippsland Lakes has been eroded along the northern line of junction of the Silurian and Mesozoic rocks, the former prevailing on the north, the latter on the south of the valley, though at one time the Mesozoic rocks must have extended right across, where the La Trobe and Lang Lang Valleys are now, and flanked to a considerable height the southern slopes of the Silurian and granite ranges from Berwick to the Tyers River. On the southern boundary of the South Gippsland Mesozoic area a channel has similarly been eroded, where Corner Inlet and Shallow Inlet now lie, along the line of contact of the Mesozoic rocks with the Silurian and granite; so that the section across from Wilson's Promontory to the north of the La Trobe Valley shows deeply-excavated channels at either side, separating the ranges composed of Mesozoic rocks from the granite and Silurian mountains to the south and north. (Fig. 46.)

In the same way the rocks of the Mesozoic ranges of the Cape Otway district have been, in a manner, isolated from the older mountain masses, which they once extended to and flanked. Such remnants of Mesozoic rocks as that near the Tyers River on

the north of the La Trobe Valley show, beyond question, that the Mesozoic rocks once flanked the slopes of the main mountain system.

FIG. 46.



a Granite. *b* Upper Silurian. *c* Mesozoic. *d* Tertiary, sedimentary, and volcanic deposits.

It is principally in hollows and channels eroded since the formation of the Mesozoic rocks that the marine Tertiary deposits have accumulated, though the outlines of such channels may have been formed at far earlier dates, and we are therefore forced to the conclusion that the natural operations which were in progress on what is now the Victorian land surface were confined, during the latest portion of the Mesozoic and the earliest part of the Tertiary periods, to denudation and removal rather than accumulation of rock materials.

The Mesozoic rocks themselves testify that at the completion of their deposit the land was submerged to a depth at least 2,000 feet lower than at present, even allowing for the fresh-water origin of many of the beds. It can only be inferred, therefore, that towards the close of the Mesozoic period an upward movement took place, and that during long ages the action of fluviatile and littoral denudation on a rising land surface sculptured and eroded the previously-formed rocks, and made inlets and straits near the coast line, insulating such tracts as the Cape Otway and South Gippsland Ranges, and eroding river channels in the elevated country.

With renewed depression commenced the deposit of the Lower Tertiary formations, and at that time the aspect and orographical configuration of the country must have been very different from what it is now. Western Port and the Gippsland Lakes were connected by a strait, and another strait connected Port Phillip with Warrnambool and Portland, thus insulating from the main land the South Gippsland Ranges in the east, and the Cape Otway Ranges in the west. The sea washed the slopes of the main mountain system from the Snowy River round to the bases of the Grampians, extending in inlets up to Bacchus Marsh, Meredith, and the Leigh River Valley, and overspreading the greater part of the Western District and the low country bordering the Murray.

During the progress of deposit of the Oligocene clays, and the Miocene calcareous beds, shell-fish in great variety of species

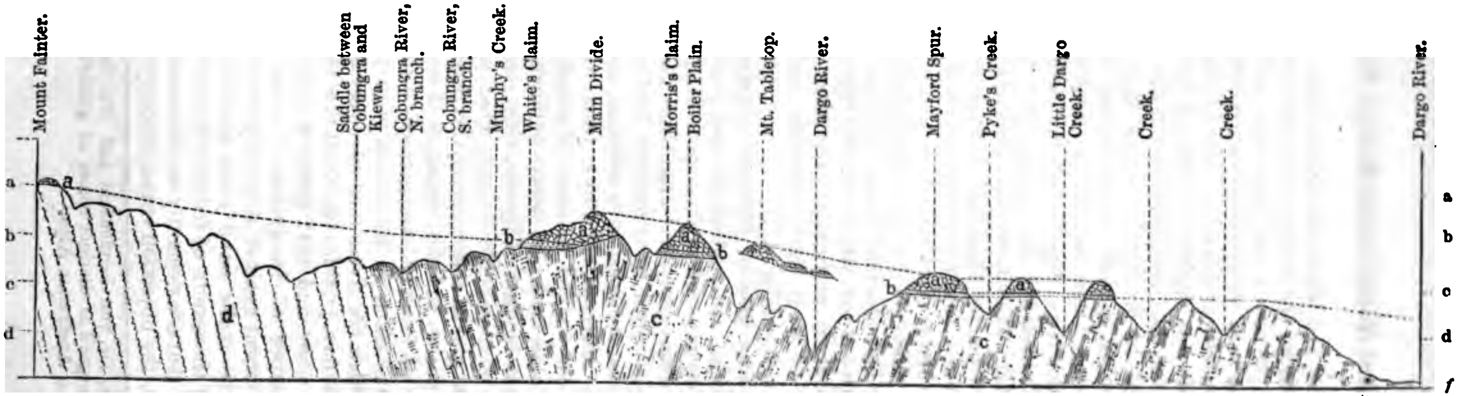
flourished in the seas, and left their remains to be entombed in the sediments; huge sharks and toothed whales lived in the waters; coral reefs fringed the coasts, and furnished the materials for the limestones. On the land we can also trace a different set of conditions to those now observable; the crest of the eastern portion of the Main Divide was further north, and the mountains were still very much loftier than now, but more in the form of elevated plateaux, intersected by broad valleys and high ridges, and less sculptured and abrupt in their configuration than at present. These conclusions are based on the appearance of the vestiges which remain of the river deposits of the period, such as the gravels beneath the basalt of the Dargo High Plains, and other places along the Main Divide, which unmistakably indicate that the streams which deposited them had their sources much further north, and, consequently, that the Main Divide of that period was further inland than the present one.

It is noticeable that the High Plains forming portion of the Main Divide, lying between the Dargo and Cobungra Rivers and Connor's Plain, between the Macalister and Goulburn Rivers, are now among the highest portions of the Main Divide, yet they represent portions of what were mountain valleys during the Middle Tertiary epoch. (Fig. 47.)

The vegetation was then of different character to that now flourishing in Victoria. Instead of the now prevailing species of eucalypts, lauraceous trees of various species appear to have predominated, the fossil leaves of the Dargo High Plains and Bacchus Marsh being, as described by Professor McCoy, of that class. Professor McCoy also remarks, with reference to one of the fossil leaves, *Salisburia Murrayi* (McCoy), from the Dargo High Plains, that it is nearly allied to some Miocene forms from the Arctic regions. Lakes occupied broad hollows along the river courses, and in them deposits of lignite, clay, sand, and mud were accumulated. It is impossible to say what part, if any, was played by terrestrial glacial action during this period, but the width of the old river deposits, and the character of the materials, indicate large volumes of water as having acted in their transport and arrangement. This, taken in connexion with the fact that the mountains from which the rivers rose were very much higher than those of the present day, justifies the belief that the loftier summits were capped with snow, and that glaciers existed in the higher ravines. The absence of ice-grooves in the rocks has been adduced as an argument against this conjecture; but when it is considered that the rocks have since been denuded for many hundreds, perhaps thousands, of feet below what was their surface in those times, and that consequently any ice marks must have been wholly obliterated, the objection ceases to carry much weight.*

* Recent observers, Dr. von Lendenfeld and Mr. James Stirling, have observed what they regard as distinct traces of glacial action among the higher portions of the Australian Alps.

SKETCH-SECTION FIG. 47.—DARGO HIGH PLAINS.



a Volcanic. *b* Miocene (Middle Tertiary). *c* Lower Silurian. *d* Metamorphic.

a 6,000 feet, b 5,000 feet, c 4,000 feet, d 3,000 feet, e 2,000 feet above sea-level. *f* Datum line.

Scale { Horizontal 4 miles / Vertical 4,000 feet } to 1 inch.

Towards the close of the Middle Tertiary period volcanic action took place, and lava-flows poured down the river valleys, filling or partly filling them in, and covering the deposits in their beds, spreading in wide layers over the lake deposits, and also partly filling up the straits or the estuaries along the coast, and covering the accumulations formed in them. This action appears to have been confined to the country lying eastward of the meridian of Geelong, as there are no visible Older Volcanic rocks in the Western District, or the country from Ballarat to Maryborough.

Several old river systems of the Middle Tertiary period, marked by the now disconnected vestiges of the lava-flows which filled them, are traceable from the eastern part of the colony round to Melbourne.

A few vestiges on the ranges or on their slopes show where valleys once existed between the Mitchell and the Snowy Rivers. The lava of the Dargo High Plains, to a thickness in some places of 800 feet, covers the deposits in the valley of an old river, which had approximately the same course as the present Dargo, but rose farther to the north-east, and whose outlet was about where the Mitchell River now enters the plain country. The basaltic plateaux of Connor's Plain, Fullarton's Spring Hill, Mount Useful, Mount Lookout, at Aberfeldy, a patch on the east side of Mount Matlock, and a basaltic area overlying gravelly deposits south of Mount Baw Baw, between the Tanjil and

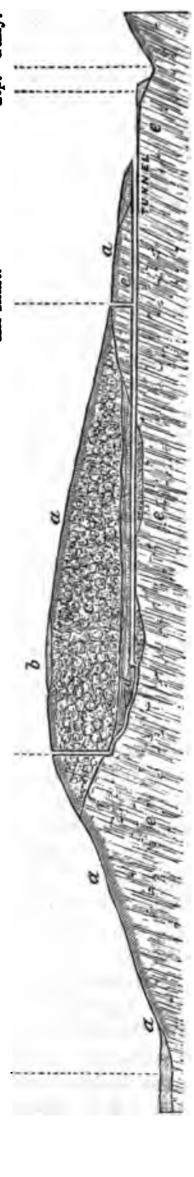


FIG. 48.
Section showing Tanjil leads as proved in the Workings of the Tanjil Gold Mining Company about 1½ miles south from Tanjil township.

a Surface soil. *b* (Pliocene) drift above Volcanic. *c* Volcanic (decomposed basalt). *d* Miocene clays, gravels, &c., beneath Volcanic.
e Upper Silurian.
Scale—Horizontal and vertical, 160 eet to 1 inch.

Tyers Rivers, indicate a river system whose course partly corresponded to that of the Thomson River, but whose sources were further north than the present Main Divide. Similar belts of Older Volcanic rocks, underlaid by gravels, indicate the existence, during Miocene times, of rivers rudely corresponding to the present Tanjil, La Trobe, and Tarwin Rivers. A succession of similar patches from Hoddle's Creek to Melbourne indicates the ancient course of a river corresponding to the Yarra. (Fig. 48.)

The wider areas of Older Volcanic rock around Neerim, Brandy Creek, Western Port, Batman's Hill, Emerald Hill, and North Melbourne, mark where the lava-flows of the period filled in lakes and estuaries to the depth in places of hundreds of feet.

It is uncertain to what extent some of these last-mentioned portions of the Miocene lava-flows which now constitute land surface may have flowed over what were at that time submerged areas. That such was the case in many places is evidenced by the occasional layers of lava found intervening between marine Miocene deposits. It may be surmised, however, that any of our Older Volcanic rocks, within 500 feet of present sea-level, were in all probability spread out under water.

Connected with the volcanic activity of the period, hydrothermal action, or the agency of heated waters, probably charged with siliceous matter, appears to have been busy, and to have influenced the transmutation of gravels, sand, clays, infusorial earth, and other deposits into flinty siliceous rocks and hard conglomerates.

Wherever the Middle Tertiary valleys were filled, or partly filled, with lava, a diversion of the courses of the drainage channels was caused thereby, and, as the work of denudation proceeded in subsequent ages, new rivers cut their channels to deeper levels than the former ones, entirely removing some portions of the older gravels and their superimposed lavas, and leaving others standing in the form of elevated plateaux and ridges. In many places the sites where the Miocene streams found their outlet to the sea have thus been obliterated by the entire removal of the lava, the gravels beneath it, and also a considerable thickness of the subjacent bed-rock. Thus, it may now be observed, that that portion of the Southern Spur from Neerim to the low saddle between the Moe and Lang Lang Rivers consists of older basalt, which covers sedimentary deposits, showing that the watershed line of the Southern Spur was not, during Middle Tertiary times, in the same position as we now see it; and, in fact, it is the rule rather than the exception, that where remnants of lava-capped Middle Tertiary fluviatile deposits are found at any considerable elevations above sea-level, they form the upper portion of eminences high above the beds of existing streams. The following extract from the work of Professor Jukes (Manual of Geology, 3rd edition,

page 620) is interesting as being descriptive of geological phenomena in Britain analogous to those which form a very marked feature in Victoria:—

"Another and striking piece of evidence (*i.e.*, as to the long continuance of volcanic action during Miocene times among the Hebrides) is given by the well-known Scúr of Eigg. That island consists of nearly horizontal sheets of basaltic rocks, like those of Mull, resting unconformably upon oolitic rocks. After their eruption, they must have been long exposed to the wasting agencies of the atmosphere. A valley was cut out of them, and its bottom was watered by a river which brought down shingle and sand from the distant Cambrian mountains of the north-west. These changes must have demanded a lengthened lapse of time, yet they took place during an interval in the volcanic history of the island. The igneous force which had been long dormant broke out anew, and poured several successive *coulées* of vitreous lava (pitch-stone) down the river-bed. In this way the channel of the stream came to be sealed up, but the same forces of waste which had scooped out the channel continued their operations. The hills which had bounded the valley crumbled away, and the lava currents that filled the river-bed, being much harder than the surrounding rock, were enabled in a great measure to resist the degradation. Hence the singular result now appears that the former hills have been levelled down into slopes and valleys, while the ancient valley occupies the highest ground in the neighbourhood, and its lava current stands up as the well-known precipitous ridge of the Scúr of Eigg. The gravel and drift-wood of the old river-bed are still to be seen under the rocks of the Scúr."

After the pouring out of the Older Volcanic lava-flows, a partial submergence appears to have taken place, as we find marine deposits of the Upper Tertiary or Pliocene period fringing the country, and often overlying the Older Volcanic rocks up to elevations of nearly 1,000 feet.

The sandy ferruginous beds of Tom's Cap, in Gippsland, and those extending from Melbourne to Frankston, belong to this class.

This would appear to have been the last important downward movement of the Victorian land, which seems to have subsequently risen gradually with a few minor oscillations to its present status.

The upper portions of the rivers which formed the deep leads of the western section of the colony—such as those of Ballarat, Daylesford, &c.—of the Upper Tertiary epoch, were probably flowing contemporaneously with those of the Miocene era, but not being filled by the Older Volcanic lava-flows, held their course uninterruptedly to a later date. The mountains in those localities

were, as elsewhere throughout the colony, loftier than they are now, and the sea was nearer to their bases. As the land rose after the last Upper Tertiary submergence, the rivers continued to erode their courses deeper, cutting through the Older Pliocene marine deposits deep into the Silurian bed-rock, their courses lengthening and their rate of decline decreasing as their sources became lowered by denudation and as the emergence of the land caused the retreat of the seas into which they emptied themselves.

The accompanying table, previously published in the Geological Progress Report No. VI., is subjoined, as conveying some idea of the operations at work during the Tertiary period in different parts of the colony :—

TABLE showing Geological operations, probably contemporaneously, in progress in the Ballarat and Gippsland districts respectively, during the Tertiary epoch :—

<table>
<tr><th>BALLARAT.</th><th>GIPPSLAND.</th></tr>
<tr><td colspan="2">LOWER TERTIARY (EOCENE AND OLIGOCENE).</td></tr>
<tr><td colspan="2">Country more deeply depressed below sea-level than at present, and coast-line nearer to the bases of the hilly country. The mountains less denuded, and consequently higher than now. Marine deposits in progress along coasts. General atmospheric and fluviatile denudation on land.</td></tr>
<tr><td colspan="2">MIDDLE TERTIARY (MIOCENE).</td></tr>
<tr><td colspan="2">Marine deposits in progress along coasts. Probable oscillations of land surface as regards sea-level.</td></tr>
<tr><td>Atmospheric and fluviatile action on land as before. Lakes in existence in which lignite deposits accumulated. Lava-flows of the Older Volcanic period took place, but not in the immediate neighbourhood of Ballarat.</td><td>Atmospheric and fluviatile action as before Lakes in existence in which lignite deposits accumulated. Lava-flows of Older Volcanic took place, filling in the greater number, if not all, of the valleys and depressions.</td></tr>
<tr><td colspan="2">UPPER TERTIARY (PLIOCENE).
Lower Pliocene Period.</td></tr>
<tr><td colspan="2">Oscillations of land surface as regards sea-level, the country being at one time depressed by about 900 feet lower than now below sea-level. Marine formation in progress along coasts to that elevation above present sea-level.</td></tr>
<tr><td>Rivers eroding their courses deeper than before, cutting through previously-deposited gravels, and leaving remnants of them on slopes. General atmospheric and fluviatile action as before on land surface. Towards the close the first lava-flows of the Newer Volcanic period took place, partly filling in the valleys.</td><td>Fluviatile and atmospheric action on land continued. Rivers commencing to cut new courses along and through the Older Volcanic lava-flows.</td></tr>
</table>

BALLARAT.	GIPPSLAND.
Upper Pliocene Period.	
Gradual rising of land surface. Marine and estuary formations in progress on receding coast-line.	
Alternate lava-flows and sedimentary deposits, the last flows covering and nearly obliterating the ancient drainage lines, after which rivers began to cut new courses through the basalt.	Fluviatile and atmospheric action continued. Rivers cutting deeper, and, in the higher country, to below the level of the ancient streams.
POST TERTIARY.	
Recent and Most Recent.	
Fluviatile and atmospheric action continued. Rivers cut their way through the lava-flows down to their present beds, forming alluvial flats as at present.	Fluviatile and atmospheric action continued. Rivers eroded their courses to present depth. Deposits of Gippsland plains completed, and lower flats and morasses formed along margins of rivers.

The Newer Volcanic lava-streams which poured from so many points of eruption throughout the western part of the colony partly or wholly filled up and concealed the rivers of the period, forming wide strips occupying the valleys from side to side in the hilly areas, spreading in broad sheets over the lower lands, and forming the great basaltic plains which constitute so important a feature in this country.

The occurrence at Ballarat of four distinct layers of basalt, separated from one another by tolerably thick sedimentary accumulations, shows that a very long period must have elapsed from the commencement to the close of the newer Volcanic period.

The basin of the Yarra affords an illustration of the successive effects of the agencies, both aqueous and volcanic, which were in operation during the Middle Tertiary and Upper Tertiary periods respectively.

We have in the remnants of Miocene gravels, covered by patches of Older Basalt, at Hoddle's Creek, and from there to Lillydale, at the Kangaroo Ground, and near the Saltwater River, the vestiges of a Miocene river system, draining approximately the same country as that now traversed by the Yarra and its tributaries, the Plenty and the Saltwater Rivers.

That the mouth of this old river was in the vicinity of Melbourne is shown by the Older Basalt occurring from Emerald Hill to Flemington, and evidently filling in an estuary of the Middle Tertiary period, though the connexion of this basalt with the patches up the Yarra Valley has been severed by subsequent denuding action. The partial filling up by Older Volcanic lava-flows of the river course, and the changes effected by littoral action during the earlier Upper Tertiary submergence, caused a

fresh channel during later Upper Tertiary times to be eroded along a different course deeper into the Silurian rocks than the previous stream. This channel was in its turn partly filled in by the Newer Volcanic lava-flows along the edges of or through which the present Yarra in the vicinity of Melbourne now winds. This basaltic strip lies between the hills of Northcote on the one side and Kew Asylum on the other, and thence passes by Hawthorn and Richmond, between Jolimont and the Treasury gardens, on the north-east, and the Government House domain on the south-west. It undoubtedly covers an ancient river bed conforming to the Yarra, and holding precisely the same relation to that river as the main trunk lead of Ballarat and Sebastopol does to the present Yarrowee River. This lava-flow, though covered with alluvial deposits below Prince's-bridge, is no doubt connected beneath those deposits with the widespread flows of Footscray and Williamstown.

Thus we have brought into juxtaposition in the Yarra basin evidences as to the fluviatile and volcanic operations of the Miocene period, which are most extensively developed in Gippsland, and the similar operations of the Pliocene era, of which the Ballarat leads are the typical representatives.

Changes with regard to the position of the mouth of the Yarra have evidently taken place within comparatively recent times. It is very evident that at one period the course of the river trended from where Prince's-bridge now stands, in a direction passing between the Barracks and Emerald Hill, and over where the Albert Park lagoon now lies, and that the outlet of the river was between Emerald Hill and St. Kilda. The erosion of a channel between Emerald Hill and Batman's Hill and the junction by that means of the Yarra with the Saltwater River must have been effected long subsequent to the outpouring of the Older Volcanic lava-flows.

It may be noticed that some of the species of fossil-fruit described by Baron von Mueller are common to both Miocene and Pliocene drifts, specimens having been found in the gravels beneath Older Basalt at Tanjil precisely identical in species with some obtained from the lead-gravels beneath newer basalt at Haddon. This tends to show that some of the Miocene types of flora continued to flourish during Pliocene times.

In some of the Upper Tertiary clays of Daylesford, however, eucalyptus leaves, akin to the present vegetation, are found in a fossil state, thus showing that at some period during Upper Tertiary times the pre-existing Miocene flora was superseded by one of a type similar to that which now flourishes.

Post Tertiary and recent action has developed the existing physical configuration. The present streams cut their way along or across the lava-sheets, sometimes adhering approximately to the

old lines of drainage, and sometimes establishing independent courses. In some places, as near Daylesford, the existing streams eroded their courses through, and to a deeper level than, the upper portions of the Tertiary rivers; in others, as at Ballarat, the latter are hundreds of feet below the present water-courses. To action which took place during Post Tertiary times are also due the surface layers of the great plains of the Murray, Gippsland, and other low-lying tracts.

The sand rocks of Post Tertiary age along portions of the coast-line, as at Warrnambool and Cape Otway, are aerial deposits formed by the action of wind blowing sand into dunes and hillocks which subsequently consolidated owing to the presence of calcareous matter derived from the shell fragments associated with them. These rocks have been partly denuded, and their materials are now in course of fresh distribution by every wind. In some places the sand is encroaching on and covering large areas of what was in my own recollection good pastoral land. The method of deposit in sloping layers, the variations in direction of the slopes, the ribbed appearance due to certain winds, and the intermixture of shell fragments, can all be observed, and to such action we can infallibly refer the origin of the consolidated beds, to which the operations now in progress present an exact counterpart.

Though, geologically, the deposits since the newer lava-flows are of very recent date, the time that has elapsed since volcanic action entirely ceased must be very great, as may be seen by the depths to which the present water-courses have cut their way through layers of hard basalt deep into older rocks, and by the deposits which have since accumulated in low-lying tracts.

It is interesting to consider the character of the fauna which flourished in Victoria and Australia generally during Upper, and even Post Tertiary times. The fossil remains found are those of animals of genera analogous to those now existing, but of vastly greater size. The Diprotodon, for instance, is described by Professor McCoy as having belonged to the same family as that now represented by our native bear or sloth; but the size of the bones found indicate that the animal was about 10 feet in length and 6 feet in height, and was able partly to gnaw and partly to tear down large-sized trees for the purpose of feeding on the leaves. Various gigantic representatives of the kangaroo tribe, some of them approaching 20 feet in height, inhabited the country, and the marsupial lion, an animal akin to our small carnivores, but equal in size to an ordinary lion, preyed upon the huge vegetable-eating denizens of the plains and forests.

The present age is essentially one of denudation as regards the land surface of Victoria. Yearly, daily, hourly, solid matter is being carried away from our mountains, and though some of it

finds a temporary resting-place on the low lands, the general effect is loss of such matter by its being carried away to form fresh deposits in the ocean bed.

The general conclusions which suggest themselves as to the Australian Cordillera are that, in Lower and Middle Palæozoic times, a continuous land surface, approximating in general direction to the present mountain system of Australia, extended from New Guinea to Tasmania; that the portion of the Victorian Main Divide, from St. Clair to the Grampians, was a great lateral spur from the Main Chain; that during the Upper Palæozoic or Lower Mesozoic periods a strait was eroded to the south of where the La Trobe and Lang Lang Valleys now lie, thus breaking the continuity of the land surface between Australia and Tasmania; that subsequently to the deposit of the Victorian Mesozoic rocks in, and the filling up thereby of, that strait, a fresh one was eroded further south, between Corner Inlet and Tasmania; that the present irregular and sinuous course of the main water-shed line is due to the successive denuding agencies which have been at work since the continent first appeared as a land surface, and that these forces have from time to time been modified or altered in their direction by the sedimentary rocks deposited in later times, during periods of submergence, or by the products of volcanic action at various epochs.

It would be tedious to attempt to describe all the cases where it is evident that portions of the crest of the Cordillera were once in different positions to the present line. Enough instances have been already noticed in this work to indicate some of the alterations that have taken place—the incalculable abrasion and degradation to which the ancient rock foundation and subsequent formations have been subjected, and the immeasurable lapse of time that must have been occupied in bringing about the present configuration of the country.

Difficult as it may be for the human mind to realize, the truth of the main principles enunciated by the late Sir Charles Lyell, and in which he has been followed by other eminent geologists, is strikingly evidenced in the geological phenomena observable in Victoria, which indicate—that to such slow action as we see now in progress in this and other parts of the world, varied by periods of greater or less intensity, changes of climatic conditions, gradual alternate submergences and risings of the land surface, and other natural causes, with occasional abnormal or cataclysmic movements, all our varied rock-formations and the alterations in the physical structure of the country from the remotest geological epochs to the present day may be confidently ascribed.

CHAPTER XI.

Dyke Stones.—Various Geological Ages. 1st Group, Non-auriferous; auriferous. 2nd Group.

Dykes of igneous rocks showing an infinite variety of mineral structure and composition intersect the Palæozoic and Mesozoic rocks in the form of injected wall-like masses of from a few inches to hundreds of feet in thickness, and are sometimes traceable for many miles, either continuously or by disconnected outcrops in some defined bearing. Some of these dykes are evidently products of Plutonic action during Palæozoic times, while others have been injected since the Mesozoic period, and there is a marked difference of mineral composition between the dyke stones of the two periods. The first group comprises numerous varieties of granite, syenite, quartz-porphyry, felsite-porphyry (elvanite), gabbro, greenstone, diorite, &c.; while the second or more recent class consists of rocks of a basaltic character, anamesite, anamesite-porphyry, basalt, lava, &c.

1st group.—Intersecting the granite masses throughout the colony are numerous dykes of very fine-grained granite, binary or half-granite (aplite), eurite, and occasionally schorlaceous granite. Granite, half-granite (aplite), syenite-granite, ternary and quaternary, granite-porphyry, syenite-granite-porphyry, felspar-porphyrite, felsite, felsite-porphyry, (elvanite), and quartz-porphyry in an infinite variety of composition and texture occur as dykes traversing granite, metamorphic Lower and Upper Silurian rocks. In different portions of any one dyke considerable diversities of composition and texture may be found. Detailed descriptions by Professor Ulrich of typical specimens of these rocks will be found in the descriptive catalogue of the Industrial and Technological Museum.

These dykes do not appear to possess other than scientific interest, not being, as far as has yet been ascertained, in any marked degree connected with the auriferous character of the quartz-veins in the rocks which they intersect. According to Professor Ulrich's descriptions of the above-named varieties the predominating felspar in all of them is orthoclase, and though hornblende occurs sometimes as an accessory mineral, and contributes the syenitic character, it is not a prevailing ingredient, and frequently occurs only in certain portions of dykes which elsewhere do not contain it.

On the other hand, the dykes of diorite and allied rocks are described by Professor Ulrich among "rocks in which the predominating felspar is triclinic (plagioclase)," as being "essentially compounds of oligoclase and hornblende, occasionally associated with quartz and mica," and "also known under the general term, 'Greenstone'—Hornblendic Greenstone, in contradistinction to the Augitic Greenstone (diabase), not yet observed in Victoria." These dykes, which will be further referred to in the chapter on auriferous reefs, &c., constitute marked and highly important mining features in the great central mass of Upper Silurian country between the meridian of Melbourne and that of the Macalister River, as with them are associated many of the auriferous quartz veins of that tract of country. They vary from a few inches to several hundred feet in thickness, and sometimes this variation takes place suddenly, as in the case of the Morning Star Dyke, at Wood's Point, which in one place suddenly expands from a few feet to nearly 300 feet in width. These dykes run sometimes with and sometimes across the strike of the Silurian rocks; thus, for instance, in the Walhalla and Wood's Point district they run north-westerly with the strike of the Silurian strata, while in the Alexandra district they have a direction often nearly east and west at right angles to, or obliquely across, the strike of the Silurian rocks. They are sometimes found rising in pinnacles or shoots at intervals along some general course, with only the "track" of a line of fissure between. Near the surface they are usually soft and decomposed into a brownish earthy rock; but, as a general rule, become hard and undecomposed at any considerable depths. In mineral composition and texture great variations are frequently observable at short distances apart in the same dyke. Some are coarsely granular and highly hornblendic, or with hornblende and felspar distinctly recognisable; others are almost structureless (aphanitic), or felstone-like in their character. Quoting from Professor Ulrich's notes in the Technological Museum Catalogue—"The extensive dyke of Gaffney's Creek, and, in a less degree, the dyke of Cohen's Reef, are in some parts distinctly crystalline granular, *i.e.*, show a granitic texture, with triclinic felspar and hornblende plainly perceptible, whilst for the greater part opened they are micro-crystalline granular, apparently quite dense, light greenish grey—felstone-like—with neither hornblende nor felspar recognisable. In fact, if it was not for the occasional changes in texture and composition just mentioned, the rock would sooner be taken to be a true felstone than as belonging to diorite, representing the variety felspathic diorite-aphanite. A fine illustration of both a textural and mineralogical change combined is exhibited by the dyke on which the Thomson River copper mine has been opened. The copper-ore-bearing part is here a coarse granular highly hornblendic diorite—in fact,

nearly pure hornblende rocks in places—which forms 'shoot-like' the northern termination of the dyke, whilst southward in strike it changes within a very short distance through finely granular to a nearly dense highly felspathic aphanite, closely resembling the rock of the Cohen's Reef and Gaffney's Creek dykes just spoken of."

Besides their ordinary constituent minerals these dyke stones are frequently more or less densely impregnated with copper, iron, and arsenical pyrites, evidently the products of natural chemical action subsequent to the injection of the dykes.

All the dykes of the first group comprising the orthoclase and plagioclase felspar divisions are pretty clearly of Palæozoic age, and the portions we now see at the present surface may have been perhaps thousands of feet below the surface at the time the dykes were injected, owing to the vast denudation that has subsequently taken place.

2nd group.—The dykes of the second group are all more or less of a basaltic character, resembling the Older and Newer Volcanic basalts. They are found intersecting the Mesozoic rocks of Bacchus Marsh and Western Port, frequently accompanying faults in the last-named locality. The "lava-streaks" of Sandhurst are simply basalt dykes, the rock of which differs little, if anything, in composition frem the Newer Volcanic basalt of the plains, except in being generally decomposed to a soft soapy clay. These dykes are to all appearance of Tertiary age, and do not appear to be in any way connected with the auriferous character of the lodes which they intersect. With respect to origin, many of the dykes of the various classes referred to, especially the non-auriferous of the first group and the lava dykes of the second group, are clearly of Plutonic origin, *i.e.*, they were injected in a molten or plastic condition, as evidenced by the alteration of the rocks which they traverse at the planes of contact; but in the cases of most of the auriferous dykes examined by me, and notably the typical one of Cohen's Reef, at Walhalla, all signs of contact alteration are absent, the planes of demarcation between the dyke stones and the containing slates are clearly defined; and yet there is no visible sign of alteration in the latter, such as would naturally have been effected had the dykes been injected in a *molten* state. I am led, therefore, to the belief that such dykes were in great measure the products of hydrothermal action, and that when injected into the fissures of the Silurian rocks they were rather in the condition of super-heated mud than of actual fusion; that their development was due to mixed mechanical and chemical action, differing from the distinctly mechanical intrusion of the molten dyke masses on the one hand, and the chiefly chemical deposition of mineral vein-stones on the other.

CHAPTER XII.

Auriferous Quartz-veins in Lower and Upper Silurian rocks.—Auriferous belts. Modes of occurrence of Gold. Other Minerals. Theories as to the formation of Quartz-veins. Nuggets. Auriferous character of Lodes at great depths.

AURIFEROUS QUARTZ-VEINS.

In the preceding portion of this work no notice has been given to the auriferous veins, lodes, or reefs of quartz which form so significant a feature in the geology of the Silurian rocks, and which now, and will for a long time to come, exercise so important a practical bearing on the prosperity of Victoria. Remarks on this subject have been purposely deferred to the concluding portion of the work, so as to admit of the discussion of the auriferous quartz-lodes in their scientific and practical aspect, in the light of what has already been said on the general geology of the country. It is unnecessary to describe all the various forms and combinations in which lodes or veins of quartz occur; the principal have been already described in the numerous publications issued by the Mining Department, and it is enough to say that in every district, in every line of lode, and in every mine, differences may be observed, due, no doubt, to local conditions present at the time the veins were being formed, or to some subsequent movements and displacements of the rocks containing them. In fact, no two lodes are alike exactly, any more than two trees, though in general features a certain resemblance to a greater or less degree is traceable.

A marked difference, however, may be observed in some respects between the reefs traversing Lower Silurian and those intersecting Upper Silurian rocks. In the case of the former, the veins traverse the rocks themselves, and, where dykes of igneous rock occur, these are usually found—as evidenced by the fact of their occasionally intersecting the quartz veins—to be of more recent date than the latter, and though frequently of value as guides to the miner, they do not appear to have in any way influenced the auriferous quality of the quartz.

In the Upper Silurian rocks, the auriferous quartz-veins very frequently are found to traverse, accompany, or intersect from side to side, dykes of diorite of older date than themselves, and with the presence of which their auriferous quality appears to be closely associated.

In the Lower Silurian rocks, the general features are the same throughout, though each district exhibits special peculiarities. The lodes or veins of quartz, from the thickness of a knife-blade to that of scores of feet, traverse the rocks, usually in directions coinciding with the strike of the uptilted strata, but sometimes crossing it horizontally, obliquely, or vertically. They exhibit the same variations as do other mineral lodes, swelling alternately into thick masses and dwindling to mere threads, or disappearing entirely either in a vertical or horizontal direction, holding even undisturbed courses for long distances, or broken and displaced by faults or slides, forming "saddle reefs," as in the Sandhurst district, and dipping to the north or south in their lines of strike; or flat reefs, as at Stawell, and holding courses independent of the strike and cleavage of the containing rocks.

In the Upper Silurian rocks some reefs occur similarly to those in the Lower Silurian, but they are, as before stated, very frequently associated with diorite dykes, in or with which they occur in every conceivable variety of form—as well-defined lodes, accompanying the dykes on either wall, or intersecting them in directions parallel with their courses; as vertical to nearly horizontal veins crossing the dykes from side to side, but not extending into the Silurian rock, or only to short distances; and as irregular strings, veins, and bunches.

Throughout both Lower and Upper Silurian areas the auriferous reefs, whether traversing the rocks themselves or the intrusive diorite dykes, occur in long belts conforming generally in direction to the strike of the Silurian strata.

Within each belt are a greater or less number of different lines of quartz reef, and between the belts are varying widths of country in which little or no gold can be found, though the rocks are of the same character, and the quartz reefs as numerous as in the auriferous areas.

Certain portions of the belts are richer than others, and intervals or breaks occur along them, where they appear to be non-auriferous; but when the different proved auriferous portions are marked on a map, their occurrence within tolerably well-defined parallels becomes very noticeable, and affords numerous suggestions for further exploration in search of both quartz and alluvial gold-workings.

The auriferous belts are, as far as been proved, narrower, and further apart, and the lines of quartz reef fewer in number, and, as a rule, smaller in size, in the Upper than in the Lower Silurian rocks; but, on the other hand, the average yield of gold per ton of quartz from the former has hitherto considerably exceeded that from the latter.

Another circumstance may here be noted, namely, that all the largest nuggets obtained in alluvial workings have been found where Lower Silurian rocks prevail. I am not aware of any

nugget greatly exceeding 100 ozs. in weight having been found in any of the Upper Silurian gold-workings to the east of a line from Melbourne to Heathcote. Though this remark applies specially to alluvial workings, it may be also extended to quartz reefs, as larger masses of native gold have been found in reefs traversing Lower Silurian rocks than have been discovered in the Upper Silurian quartz-veins.

The forms in which gold occurs in the reefs are various. It is sometimes evenly distributed through the stone, but is more frequently confined to some particular band, either on the foot or hanging wall, or, more rarely, in the central portion of the vein or lode. The auriferous portions of the stone in some places take the form of irregular disconnected patches, in others well-defined zones or "shoots" of varying vertical width, which dip at different angles northward and southward in the direction of the strike of the reef. The gold itself occurs in tolerably large lumps intermixed with quartz, in strings, ragged pieces, crystals, mossy aggregations lining cavities, and in fine specks. It is also found in mechanical combination with iron pyrites, a mineral almost universally present in greater or less quantity in all quartz lodes, especially below water-level.

Besides iron pyrites, copper and arsenical pyrites, galena, antimony, and zinc-blende, are frequent accompaniments of auriferous lodes, and in many mines one or other of these is regarded as an infallible indication of the proximity of gold-bearing stone.

Investigations as to the primal origin of gold would probably prove as futile as inquiries into the origin of any other metal or form of matter, but the question of how gold came to be associated with quartz in veins or lodes admits of at least a theoretical solution, and the first stage of the inquiry relates to the origin and history of the quartz itself.

Without entering into a description of the various different modes in which quartz lodes and veins occur, the broad fact can be stated that they occupy what were lines of fissure in the Silurian rocks. As to how those fissures were formed in the rocks a general conjecture can be arrived at. It has been shown that the Silurian rocks—originally laid down horizontally—were crumpled, folded, and contorted so that their bands finally assumed positions approaching the vertical, and that, whatever may have been the cause, the forces operating were such that the longitudinal axes of the corrugations took in Victoria, for the most part, an approximately meridional direction. Such movements could not take place without, in addition to the corrugation, considerable faulting, fissuring, and great local displacements, and the lines of fracture, naturally following those of least resistance, coincided in general direction with the strike of the schistose rock-bands.

It is scarcely to be imagined that all the fissures now occupied by quartz-veins were formed within one short period. No doubt most of them resulted from movements connected with or closely following the corrugation of the strata, whether that process was accomplished quickly or slowly; but with succeeding movements further fissures and displacements were effected from time to time, thus rendering the systems of fissures or lines of fracture more and more complex. The existence in Upper Palæozoic rocks of quartz-veins traversing conglomerates, which are themselves partly composed of rounded pebbles of vein-quartz, is in itself a clear proof that the formation of quartz-veins in fissures was not confined to the Silurian rocks, though it attained its extreme development in them. At the same time, it would appear that most of the fissures occupied by quartz-veins in Silurian rocks in Victoria were formed and occupied by their contents prior to the formation of the Upper Palæozoic rocks.

With regard to the direction and extent of the fissures, much depended on the character of the rocks they occurred in. In evenly-bedded slates the fissures would generally be regular, while in diorite dykes the shrinkage cracks would naturally be irregular, though the fissures, if any, along the walls of the dykes would be influenced, as regards regularity or otherwise, by the character of the containing rocks. In one case a clean fissure or split between two parallel rock-bands would be effected. In a second, the fissure, owing to some conditions in the directions of the operating forces, or the tenacity of the rock-bands, would follow the planes of stratification, either horizontally, but not vertically, or would intersect them obliquely in both directions. In a third instance, an abnormal displacement would cause a fissure of which one wall was clean—*i.e.*, the plane surface of a rock-layer—and the other wall irregular, on account of the plane of the former crossing obliquely the basset edges of the layers in the latter. Numerous other cases and combinations might be instanced, but the above are the principal, and serve to illustrate the phenomena now observable in mineral lodes and veins. Fissures also occurred along different portions of which all the conditions mentioned were developed. The course of a fissure diverged from between two parallel bands, and passing downwards, or laterally through one wall, established the conditions described in the second case, whence it passed into the third, &c.

Where plutonic or hydrothermal action resulted in the injection of dykes, we find that while some of those dykes found their way along the lines of least resistance or with the strike of the rock-bands, others intersected the latter across their line of strike, either obliquely or at right angles.

Admitting generally that the fissures resulted from movements of the earth's crust and the fracturing thereby of the rock-masses,

the next consideration is the method by which the quartz-veins were formed into fissures, and the associated minerals conveyed and deposited in or with the quartz. In the first place it is known that silica, the principal, or nearly the sole constituent of quartz, is capable under certain conditions of being held in solution and of being deposited from that state in various forms, crystalline, concretionary, laminar, &c. Of several theories once entertained as to the formation of quartz and other mineral veins or lodes, one was that they were deposits, in the fissures, of minerals held in solution by the sea during some period when the country was submerged, This is untenable, for the simple reason, among many others, that under such conditions the natural results would be the speedy filling up of the fissures by mechanically-formed sediments of mud and detritus, of which we find no evidence whatever. Another theory was that the quartz was injected in a molten state like an igneous dyke. This is refuted by an overwhelming mass of evidence, some of which also bears on the first-mentioned theory. The various structures exhibited by quartz, whether crystalline, amorphous, or laminated, are not those which it could be expected to assume on cooling from a state of *fusion*, whether quickly or slowly, or at whatever depth below the surface.

The walls of quartz-veins show not the least indication of having been subjected to *dry* heat emanating from such veins. In the case of quartz-veins traversing dykes, we see plainly that the latter whatever their origin, were injected first, and that in shrinkage-cracks and other fissures which formed in or along them during or subsequent to their consolidation, the quartz has since been formed in lodes, veins, strings, or bunches, in a manner wholly irreconcilable with the idea that it was ever in a molten condition; and further, we find frequent instances of bunches or small veins or patches of quartz occupying hollows or cracks remote or totally isolated from large veins, and unaccompanied by any indication of having attained that position by being injected in a molten state. Such quartz-veins are occasionally to be met with in the Upper Palæozoic (? Upper Devonian) rocks of the Avon, under conditions which preclude all possibility of their being of Plutonic origin.

Dismissing the above theories, we can turn to a third, which affords the most probable explanation. It is that the quartz veins are the results of the segregation of silica from the surrounding rocks themselves, or the subjacent Plutonic masses, and its conveyance by percolation—probably hydrothermal—waters into the fissures, where it was precipitated, according to local conditions, in the various forms assumed by quartz, much in the same way as we see calcareous veins in actual course of formation in cracks and fissures in limestones, and even in rocks containing but a small proportion of lime. If to this action was added, as it is reasonable to suppose, that of heated mineral waters, steam, and

vapours, bearing in mind that the intensely-heated portion of the earth's interior was then nearer to the surface than now, we have a set of conditions under which it is easy to conceive the formation of siliceous veins, and the deposition with, or in them, of metals or minerals which had also previously been in a state of solution or volatility, though perhaps it may not be possible to reason out exactly the various forms of chemical action which were developed during the process. The late Sir R. Daintree strongly advocated the theory that hydrothermal action arising out of deep-seated Plutonic action played an important part in the formation of quartz-lodes, and the deposit of their associated minerals.

Assuming the above general main conditions as having been in existence, the infinite variety of modes of occurrence of quartz-veins and associated minerals can be reasonably attributed to them, though their action was evidently subject to local modification as regards degrees of intensity, or influenced by such mechanical forces as may have been contemporaneously in operation. Thus we find that one quartz reef consists of white amorphous quartz; another is more or less evenly laminated; a third shows marked crystalline structure; in a fourth, the lode contains on one wall quartz of a different character to that occurring on the other, and the two kinds may be found to be separated by a clean parting or to merge into one another. Two or more of the foregoing features may be found in different parts of the same line of lode. Gold or other minerals may be found near one wall more than the other, or any other of the phenomena encountered by the miner in connexion with quartz-veins may be mentioned; but there are none that I have seen or heard of that are not susceptible of explanation under the segregation and hydrothermal theory, allowing for different degrees of rapidity of action, intensity of heat, the predominance of certain minerals or vapours in one locality over another, and the various displacements due to further movements of the earth's crust which took place during or subsequently to the deposition of the vein-stones.

It is not necessarily to be inferred that the fissures to which the mineral waters determined were from the first as wide as the veins which now fill them. No doubt successive re-openings, caused by earth-movements, and enlargements of the fissures, effected by the passage of moving waters, enabled successive depositions of quartz and other minerals to be produced, and to this, no doubt, may be attributed the circumstance of some particular band in a reef being usually more auriferous or more highly mineralized than another. As a rule, it has been observed that laminated or seamy quartz is usually more highly auriferous than that of a massive amorphous character; and the idea has suggested itself that the latter was formed quickly, there being an excess of siliceous matter present, and the metallic minerals not present in proportionate quantity; whereas, in the case of the

laminar quartz, the deposit proceeded slowly in successive coats, thus giving time for the associated deposit of the rarer minerals. Much of the finer free gold, in portions of lode above water-level, may have been originally in mechanical combination with pyrites which have since decomposed.

With respect to the primal origin of the gold itself, it can be no better accounted for than can that of iron, lead, or any other metal or form of matter; but with regard to its association with the Palæozoic rocks, there is an hypothesis available, the advancement of which can at least do no harm. The conjecture is based on the known presence of a minnte proportion of gold in sea-water, and it is supposed that when the Silurian rocks were being laid down, gold was present in the water in greater quantity than now; that much of it was gradually precipitated and deposited either free, or in chemical combinations, with the sediments as they slowly accumulated, and that after the consolidation and upheaval of the strata, permeating heated mineralized water, both of meteoric origin and incorporatel with the rocks, conveyed the gold in solution in company with the silica to the vein fissures, where it was segregated into grains, strings, and crystals, forming masses of greater or less size, from invisible specks up to large nuggets, according to the intensity of the agencies at work. Premising with the remark that the theoretical views advanced are only given as a working hypothesis to be held with a loose grasp, and likely to be modified by new facts, Mr. A. W. Howitt, from whom I first acquired the idea, has generously placed at my disposal the following notes, which I quote *in extenso.*

"1. I assume the existence of gold in solution in the Palæozoic seas.

"2. The Silurian sediments, during their formation, necessarily included a large amount of sea-water (organic matter may have precipitated gold in a metallic state, and in a finely-distributed condition, throughout and in these sediments).

"3. This included sea-water could not escape until the sediments were raised above sea-level.

"4. The geological evidence shows that before being so raised they were folded, compressed, and depressed within the influence of the internal heat of the earth. (It is immaterial whence this heat was derived—possibly due to the molten interior, and heat resulting from motion in the crushed sediments.)

"5. The sediments were then invaded by molten rock masses from below; were metamorphosed, melted, and absorbed as to their lower portions; the molten material was forced upwards through the line of least resistance to the surface, and gave rise to the Palæozoic volcanoes, *e.g.*, of the Snowy River. The great masses of molten material on final consolidation are represented by the granitic rocks underlying all Victoria.

"6. The salts in solution in the sea-water included in the sediments, and the materials of the sediments themselves, reacted upon each other under the influences of heat and pressure.

"7. The mineralized waters would find passage through the contact planes of the igneous and sedimentary rocks, and by fractures in the strata, &c.

"8. On the cooling down of the rocks, the waters would likewise lessen in temperature, and deposit their metallic and mineral substances which they had 'leached' out of the sediments; would deposit them in the contact planes, faults, and fissures. Faults which had been penetrated by dykes would also afford passage to such waters, and to sublimations, *e.g.*, Cohen's Reef and also 'Steam-boat Springs of California.'

"9. All the saline solutions in the Palæozoic seas would enter into reactions, and even if the gold had been reduced by organic substances, it would, I think, be again chlorinated on the regeneration of the felspars out of the materials of the sediments and the alkaline chlorides and chloride of calcium in solution.

"It seems to me, therefore, probable that we may refer the formation of auriferous veins and metalliferous lodes, generally occurring in the Silurian and Devonian formations, to Plutonic and volcanic action, which prevailed about the close of the Silurian period and onwards, until our geological record closes in the Upper Devonian. But we must also take into account a secondary process which is always going on in the reactions produced by meteoric waters percolating from the surface downward; this process is partly one of decomposition and partly of concentration.

"The conclusions I arrive at are, therefore—First, that the gold has been collected out of the sediments during the Plutonic and volcanic action in Palæozoic periods; second, that it has been (at the surface) undergoing concentration, partly by the removal or decomposition of metallic ores. We know that auriferous reefs very frequently, if not almost always, occur in bands along the strike of the sediments. In accordance with the above views, I suggest that these bands represent extensive fractures, communicating downwards with the planes of contact of the igneous and sedimentary formations. Such extensive fractures would give passage to heated mineralized waters and to sublimations. As to these bands, I think we may assume the following:—

"1st. The folding and compression of the Silurian rocks was consequent upon the contraction of the earth's crust through cooling of the globe.

"2nd. That fractures would most probably occur along the axes of anticlinal and synclinal folds.

"3rd. The pressure of a folded and depressed portion of the earth's crust upon the molten material beneath would afford a sufficient *primum mobile* to produce the upward thrust of liquid

rock masses through fissures, and generally against the overlying sediments. This pressure, produced by the contracting crust, would suffice to produce volcanic outbreaks, without calling in aid 'waves of the molten interior,' &c. Nor could steam be called in to produce the upward motion of the molten rock until it (the rock) rose to within such a distance of the surface that the pressure of the column of rock (or of molten rock) was no longer sufficient to keep water fluid."

The occurrence of auriferous quartz-veins in belts may—assuming the above supposition to be correct—be due to the circumstance that a greater amount of gold was deposited in certain sets of layers than in others, and that when the rocks were uplifted from a horizontal to a vertical position, those bands which contained most gold yielded the largest supply for deposition in the quartz-veins, while in others containing little or no gold only poor or barren quartz-veins were formed. I am aware that many difficulties will have to be surmounted before the above theory can take the position of an universally accepted explanation; but in the meantime it claims to be a good working hypothesis, founded on well-digested information, and likely at no distant date to rank —subject to a few modifications—among the established deductions of science.

With regard to the occurrence in alluvial deposits of nuggets or masses of gold, far exceeding in size any found in the quartz-reefs themselves, and the consequent difficulty of reconciling this circumstance with the belief that all alluvial gold has resulted from the degradation of quartz reefs, it may be observed that many of the large nuggets found in alluvial deposits have been intimately mixed with vein-quartz in such a manner as to leave no room for doubt as to the latter having formed portion of the original matrix. Some nuggets have been found on which distinct impressions of quartz crystals were visible, and in nearly all large nuggets there is a certain "honeycombed" or "ragged" appearance in those portions that have not been smoothed externally by attrition.

I do not lose sight of the hypothesis formed by Mr. Selwyn, that pieces of gold disintegrated from quartz reefs may have been subsequently added to in the drifts by deposit of gold from solution by meteoric waters. This was supported by the experiments of Sir R. Daintree and Mr. C. S. Wilkinson, who proved that the presence of organic matter or pyrites caused the deposit of metallic gold from solution. It has also been urged in support of this belief, that the largest nuggets were found where volcanic eruptions, as at Ballarat, had favoured the development of highly mineralized waters, and that in parts of Gippsland and other places where there has been no volcanic activity, pieces of gold above a few ounces in weight are rare.

Now, as a matter of fact, many of the largest nuggets that have been found were discovered between Moliagul and Wedderburn, close to the surface, in country where there is no indication of volcanic action having ever taken place; while, on the other hand, no pieces over 40 ozs. in weight have been found in the gravels beneath the older basaltic layers in Gippsland, where one would suppose the conditions for the development and action of mineralized waters would have been equally, if not more, favorable, and also of longer duration that at Ballarat.

I cannot help thinking, therefore, that the augmentation of pieces of gold by further deposit from the surrounding meteoric waters must have been very trifling, if it took place at all; that the large nuggets were originally formed in the quartz reefs, and subsequently disintegrated therefrom; and that the occurrence of larger masses of gold in one part of the country than in another is due to the conditions under which the gold was first segregated in the quartz-veins having been more intense in one group of rocks than in another.

Tolerably large lumps of solid gold, or intermixed with but a small proportion of quartz, and many ounces—in some cases pounds—in weight, have been actually found in quartz reefs, and those which I have inspected all looked as though, if subjected to the long continued action of moving water in company with pebbles and other hard fragments, much, if not all, of their associated quartz would be removed out of them, and the gold beaten and welded into more compact form. It is not unreasonable to believe that if a mass of gold one pound in weight could have been formed under certain conditions in a quartz matrix, a mass of 200 pounds or more might have been formed under similar but more intense conditions, perhaps accompanied by additional conditions favorable to the segregation of gold in larger masses than ordinary.

Assuming the correctness of the previously enunciated theory as to the general mode in which quartz and associated minerals were segregated into veins, we have, in addition, the certainty that those portions of quartz reefs which we now see at the present surface were really formed at great depths below what was the surface at the time they were in process of formation. Enough has been said in the portions of this work devoted to geological history to show that the denudation to which the Palæozoic rocks have been subjected is simply incalculable. Most, if not all, of our quartz reefs appear to have been formed during Palæozoic times, and consequently their original upper portions have been removed by the denuding action of subsequent ages; it is quite possible, therefore, that when they were in process of formation the conditions near the then surface were more favorable than at considerable depths to the accumulation of the gold in large masses, and that the large nuggets found in our alluviums were originally

segregated in portions of the quartz reefs which have since been entirely removed, leaving their disintegrated gold to drop gradually as the surface became lower by abrasion.

Much has been said about the alleged prediction of Mr. Selwyn, and other geologists, to the effect that quartz reefs would cease to be auriferous below a depth of 400 feet. The general opinion which has been tortured so industriously into a dictum, was published many years ago when quartz mining, both in California and in Australia, was in its infancy, and this opinion was simply to the effect that, in the light of experience obtained in European and Asiatic gold mining, auriferous quartz lodes were more likely to decrease than to increase in richness as followed downwards, and would probably become unremunerative within limited depths. Mr. Selwyn personally, however, maintained the view that such decrease would be inappreciable within the limits attainable by human skill. The opinion has happily proved correct; our subsequently acquired experience here shows that many of the lodes yield good returns from depths exceeding 1,000 feet, and, at Stawell and Sandhurst, rich yields have been obtained from double that depth, so that the question as to whether deep quartz mining will pay is practically answered in the affirmative as far as our more important quartz mining districts are concerned. Mr. Selwyn did not fail to record his conviction that there was no reason to doubt but that quartz gold mining would prove as permanent a source of wealth here as tin or copper mining in England. In some places, however, quartz reefs, payably auriferous while in Silurian rock, have been followed down to subjacent granite, and have there been found to thin out and become unprofitable; so that there is evidence, at all events in some cases, of the granite, at whatever depth it may be encountered, forming one limit to the successful downward prosecution of quartz mining. I here refer to granite as a mass or portion of the hypogene rock foundation, and not as a dyke or injected vein; in the latter form granite or some kindred rock may be found to contain payably auriferous quartz-veins to indefinite depths while traversing Silurian rocks. Admitting that there is nothing to preclude the hope that many of our quartz mines may yield profitable returns from the utmost depths to which human skill can penetrate, the first portion of the opinion above referred to—as to probable decrease in richness of the lodes as followed down—has not so far been refuted by experience, though it is no doubt amenable to considerable modification. The fact can hardly be gainsaid—giving due credit for exceptional rich yields from great depths—that, on the average, richer quartz has been obtained from the surface portions of the reefs generally than has been met with in the deep levels, and though our lodes may be practically inexhaustible, there is nothing to justify the expectation of an increased yield from them as followed downwards.

To judge by the extraordinary richness of many of our alluvial workings, and the size of the nuggets found in them, as compared with the yields obtained from the auriferous quartz reefs near them, the conclusion suggests itself that the denuded upper portions of those reefs, whence the alluvial gold was originally derived, must have been far richer than what remain intact, even allowing for the denudation of the Palæozoic rocks and their associated quartz-veins, for a thickness of many hundreds or even thousands of feet in vertical height above the present surface, and the concentration of the gold thus disintegrated into gravelly deposits of comparatively limited extent. With the fact of our surface quartz having so far proved of greater average richness than that obtained from considerable depths,* and the strong evidence that the quartz which has been denuded, and from which the gold of the alluviums has been disintegrated by geological action, was even richer still, the general correctness of the first portion of the opinions referred to remains unchallengeable, though enough has fortunately been proved to justify sanguine hopes as to the future progress of deep quartz mining, and to warrant the expenditure of capital in its development.

* The quartz-mines of Sandhurst afford a notable exception to this rule.

CHAPTER XIII.

Alluvial Gold Drifts.—Auriferous Miocene Gravel. Auriferous Palæozoic Conglomerates. Tertiary Gold Drifts of different periods. Different Classes of Alluvial Gold Mining. General Geological History of Gold Drifts.

Under this head I here include any auriferous detrital deposit in the form of earth, rubble, clay, sand, drift, gravel, conglomerate, or cement—as distinguished from vein-quartz or matrix rock—whether deep or shallow, loose and incoherent, or consolidated, and of whatever geological age, from Upper Palæozoic to Post Tertiary. All Victorian gold drifts yet worked are of Tertiary or Post Tertiary age, and were provisionally classified by Mr. Selwyn in three principal groups, referable respectively to the Older Pliocene, Newer Pliocene, and Post Pliocene epochs.

About twenty years ago, Mr. Selwyn advanced a strong opinion as to the non-auriferous character of gravels of Miocene or Middle Tertiary age, and based it on the non-discovery of gold in certain gravels of that age which were prospected by the geological survey party then at work near Steiglitz, and the alleged failure of a mining company to obtain gold in a very deep deposit of Miocene age at Morrison's diggings, on the Moorabool, though the Pliocene gravels resting on the "false bottom" formed by the Miocene deposit had been profitably worked.

I have been informed, however, that, during the operations of the company in question, a small quantity of gold was obtained on reaching the Silurian bed-rock, but that work was discontinued before reaching the deepest ground, where any considerable quantity of gold that might exist would naturally be expected to be found.

Subsequent investigations have shown that payably auriferous gravels of the Miocene period occur beneath the older basalt of various parts of Gippsland, and in the Yarra basin, so that the mere fact of a gravel or drift being of that period is no evidence as to its being non-auriferous. In New South Wales, a conglomerate of Upper Palæozoic age resting on Silurian rocks has been found to contain alluvial gold in fair quantity, and in pieces up to several ounces in weight, so that there is no reason whatever to doubt the possibility of finding payable gold in any detrital deposit younger than and resting on Silurian rocks. There is very good evidence to the effect that the quartz reefs and their associated gold had been deposited in the vein fissures prior to the formation of the Upper Palæozoic rocks, and, therefore, such gravels or conglomerates of Upper Palæozoic or more recent date,

as rest immediately upon and are made up of detritus derived from Silurian rocks, are certain to contain gold in the vicinity of where the latter are traversed by auriferous quartz-veins.

It so happens that in the neighbourhood of most of our gold-fields conglomerates of Upper Palæozoic or Mesozoic age do not occur, or have not been tested, but there are places where it is reasonable to expect that the *lowest* beds of such conglomerates, *where resting immediately on the Silurian bed-rock*, might be found auriferous. These localities will be mentioned hereafter, though to test them would be a matter involving considerable outlay and only to be entered upon after ascertaining beyond a doubt the auriferous character of exposed Silurian rocks within reasonable distance.

Among the tertiary gold drifts we can now identify those of at least four distinct periods. (1.) That of Miocene or Middle Tertiary age formed prior to the outpouring of the Older Volcanic lava-flows. (2.) That classed as Older Pliocene, which in some places appears to be of marine or littoral deposit, and in others the result of fluviatile action. (3.) The deep lead gravels occupying gutters or channels cut through, and therefore newer than the Older Pliocene gravels, but older than the Newer Volcanic lava-flows. (4.) Post Tertiary drifts and gravels, more recent than the newer basalt, and made up of materials derived from the denudation of some of the foregoing or from recently effected abrasion of the Silurian rocks.

The different modes of occurrence of alluvial gold are so familiar to our miners that it seems almost superfluous to describe them, but it is as well to mention the principal classes of alluvial gold workings in order to elucidate the remarks on the geological action by which the gold was conveyed into the different positions in which it is found.

1. Surfacing.—Earth or thin layers of clay, rubble, and decomposed rock on the slopes or summits of hills composed of Silurian rocks. The gold is found free or associated with fragmentary quartz, from the surface-earth down into the chinks and crevices of the bed-rock. In some cases the gold thus found has been derived directly from some line of quartz reef traversing the Silurian rocks, and is found to be "ragged" and unaltered in form; in other instances a gravel drift has at one time existed, and has been wholly or partially removed, and the water-worn gold once contained in it—primarily derived from the disintegration of quartz reefs—has been left behind, and has simply dropped deeper as the rock surface became abraded. Combinations of the two cases are frequent, and some of our reef-washes, or other auriferous alluvial deposits on slopes of Silurian rocks underneath basalt, represent the precisely similar conditions which existed in former ages and have been preserved from further change by the covering of volcanic rock.

2. River, Creek, and Gully Workings.—The deposits of gravel, drift, &c., resting on the Silurian rocks in the beds or on the banks of water-courses. These deposits vary from a few inches to many feet in thickness; the gold is usually found low down in the gravel, on the bed-rock or deep in its crevices; in river valleys, terraces of auriferous gravel are sometimes met with on the rocky slopes high above the river beds. These appear to be vestiges of deposits formed before the water-courses had eroded their channels to so great a depth in the bed-rock as they have since reached. The gold in all these deposits has been either derived directly from the disintegration of the quartziferous Silurian rocks, or from the denudation and re-distribution of pre-existing drifts.

3. Leads.—Gravels, conglomerates, &c., of Middle or Upper Tertiary age, deposited in the beds of ancient rivers, in some places only covered by recent accumulations, and in others by one, two, three, or four distinct layers of basalt. To such may be added some "reef-washes," which have been formed during intervals between the outpouring of two different lava-flows. The beds of these ancient rivers are in some localities above, and in others below, those of existing streams, and are worked by tunnels or shafts accordingly.

4. Gravels, conglomerates, &c., apparently due to marine littoral action; these are generally more widely spread than the lead gravels; the gold is more "patchy" in its occurrence, though sometimes found in defined "runs," not necessarily in the deepest hollows of the bed-rock, but often on the ridges or slopes thereof. Some of these deposits cap hills of Silurian rock; others constitute "reef-washes" beneath the basalt, but at higher levels than the deep lead gutters. Though the above embrace the chief forms of auriferous alluvial deposits, there is an infinite variety of combinations to be met with, but all attributable to the same principal cause—denudation by atmospheric and aqueous action of the Silurian rocks and their accompanying quartz-veins. It is not to be supposed, however, that all our alluvial gold was disintegrated from its matrices only since the commencement of Tertiary times. We have such irrefragable proof that denundation has been acting on the Silurian rocks from their first appearance as a land surface, that it is only reasonable to believe that considerable proportions of the gold found in, and the materials composing, the various auriferous gravels, were disintegrated from the matrices and rock-masses during Upper Palæozoic and Mesozoic times.

The water-worn character of the pebbles and boulders, and also the gold itself in the gravels quite close to the apparent sources whence their materials were derived, indicate that the fragments were broken from the rocks and rounded by forces acting prior to the agencies which finally deposited the gravels, and that these are for a great part re-distributions of pre-existing deposits

combined with the results of further denudation of the Silurian rock-masses. A considerable portion of the materials now composing the Upper and Post Tertiary gravels, and the gold associated with them, may have once formed part successively of Upper Palæozoic, Mesozoic, and Lower and Middle Tertiary detrital deposits; denudation during each succeeding period having sifted and re-arranged the materials, removing the soft and friable, leaving the harder fragments more and more water worn, and making further encroachments on the Silurian rocks. Throughout all changes, however, the larger disintegrated particles of gold, owing to the high specific gravity of the metal, appear to have been conveyed to but comparatively short distances from the parent quartz-lodes. Once freed from its matrix, the natural tendency of a fragment of gold of any appreciable weight is merely to drop deeper, as the surrounding or subjacent materials are removed, and though much of the gold in the leads has probably travelled for some distance, it appears to have done so principally while attached to portion of its matrix, or when in small particles in company with masses of other materials which carried it along with them; or when a smooth bed-rock offered no resting place.

On this circumstance may be founded a principle that, where there are auriferous alluviums, there are likely to be auriferous quartz-veins at no great distance. Though by no means new, this principle has not hitherto been recognised in its full importance, and there is reason to believe that its judicious application to extensive and systematic prospecting would result in a largely increased development of quartz-mining throughout the colony.

CHAPTER XIV.

Suggestions for further development of Gold Mining—quartz and alluvial. General principles. Auriferous zones, or belts, described according to geographical position from west to east. Metals other than Gold.

In indicating the directions in which mining exploration in search of auriferous gravels and quartz reefs appears most likely to prove successful, two circumstances, already pointed out, have to be kept in view, as forming a basis on which to arrive at a reliable conjecture as to the probable auriferous character of any particular locality.

The first is the known occurrence of auriferous quartz reefs—whether in Silurian rocks, or in dykes traversing the same—in belts or strips of varying width, but of undefined longitudinal extent. The second is the strong indication afforded by the presence of any considerable quantity of gold in alluviums, as to the close proximity of auriferous quartz reefs; and conversely, the likelihood, or indeed certainty, of finding alluvial gold in detrital deposits, derived from and in the vicinity of rocks containing auriferous quartz-veins.

The principal belts containing auriferous quartz reefs are now tolerably well known so far as the country consists of exposed Silurian rocks, and, in some places, the quartz reefs are being worked on their extensions beneath alluvial deposits and volcanic layers. Between these belts occur tracts of country which, though consisting of Silurian rocks traversed by quartz reefs, have, in spite of careful prospecting, failed to yield gold in remunerative quantity, though, no doubt, there may be in such apparently non-auriferous tracts minor belts or lines of auriferous quartz reef which have hitherto escaped observation. The lateral limits of the proved portions of the auriferous zones are, however, sufficiently well defined, and their lines of strike sufficiently well marked to furnish data for guidance in prospecting on the northward or southward longitudinal extension of such zones. That these zones do not maintain their auriferous character throughout their entire lengths is evident; but it would appear that on their lines of strike the quartz reefs within their limits are auriferous for various lengths, increasing in richness in one locality and diminishing in another. In fact, as a single line of quartz reef is generally found to contain gold in successive shoots, separated by barren intervals, so do the belts comprising each a number of quartz reefs exhibit the same phenomenon. So long as the country

consists of exposed Silurian rocks, the belts can easily be followed, and the quartz reefs or alluvial deposits tested at or near the surface; but when we consider the comparatively small width, north and south, of the exposed Silurian rocks composing the western portion of the main mountain system, in which our richest gold-fields are situated, and the maintenance of their character from place to place by the auriferous belts within that width, we are led to the conclusion that by following the lines of extension of those belts, and penetrating the newer formations overlying the Silurian rocks northward or southward of the Main Divide, we are likely to discover fresh groups of auriferous quartz reefs traversing the concealed bed-rock and auriferous gravels overlying it in their vicinity. This remark applies not only to Victoria but to the entire breadth of Australia, from Victoria to the Gulf of Carpentaria, for there is no reason to doubt the continuance of the Victorian group of auriferous belts beneath the newer formations of the western portions of New South Wales and Queensland. There is even a fair probability of discovèring payable alluvial gold in the lowest beds of Marine Tertiary, Mesozoic, or Upper Palæozoic formations where these consist of gravels or conglomerates, and rest immediately on Silurian rocks on or near the lines of extension of any of the known auriferous belts. In fact, considering that in such localities the Silurian rocks have very likely been subjected to greater degradation than in the mountain districts, and bearing in mind the tendency of gold to remain nearly stationary during the removal of large quantities of other materials, it is not unreasonable to infer that gold may thus be found in large quantity, though probably more widely and irregularly distributed than it would be in narrow leads of fluviatile origin.

No doubt the difficulties to be encountered would be great, and search in such directions would not be justified except on excellent data obtained where the Silurian rocks were near the surface; but nevertheless, there are reasonable grounds for hope that, with increased knowledge and improved mining appliances, the auriferous belts will, at some future date, be traced for a far greater length than they may be at present supposed to extend to.

It would be impossible to say how deep it would be necessary to sink before reaching the bed-rock in the Murray Valley for instance, but I believe that in any portion of it lying to the eastward of the meridian of Stawell, the greatest depth would not exceed 1,000 feet. In the meantime, however, there is abundant scope for exploration in search of gold, whether quartz or alluvial, in localities where the depth would be comparatively trifling, and where the proximity of proved auriferous country would warrant the expenditure necessary to prosecute the search. I will therefore now proceed to briefly describe the principal known auriferous belts from the western to the eastern portions of the colony, and

to indicate on their lines of extension, northward and southward, where mining explorations would be attended with a fair chance of success. It must be understood, however, that the sequence of the gold-fields of each belt, in relation to lines of strike, can only be indicated approximately.

The Geological Sketch-map of Victoria will be found a valuable adjunct to the perusal of these remarks, and if intelligently used by intending prospectors, will assist them to conduct their operations with reasonable prospects of success.

The westernmost gold-field in Victoria is that of Moyston, where a moderate extent of alluvial ground and one or two rich lines of reef have been worked. The reefs after being followed with good results to a depth of 400 feet or more, are at present unworked, though by all accounts there are good inducements to attempt to trace them further. Approximately in the line of strike of the Moyston reefs is the Frying-pan gold-field, where some good finds were made, though little is being done at present. The continuation of this belt northward and southward is likely to contain other alluvial deposits and quartz reefs.

The next belt eastward is a very important one, containing as it does Stawell, and the diggings northward and southward, the Great Western, Armstrong's, and Ararat gold-fields. An area of exposed granite breaks the continuity of this belt between Stawell and Great Western; but there is every reason to expect that by following the strike of the rocks northward from Stawell, more gold-bearing "shoots" will be found in the quartz reefs, and fresh alluvial deposits opened up in the gravels and conglomerates.

Ararat, though of great extent and richness as an alluvial field, is so far unimportant as regards quartz mining; but it is difficult to believe that where the alluvial has been so productive, there are not rich quartz reefs in the vicinity, either in the hills or concealed beneath the alluvial deposits. The main lead of the Hopkins Valley, the outlet of the principal leads of Ararat, is likely to prove rich where its position has lately been ascertained by means of diamond-drill bores, just where, after a deviation to the east, away from the auriferous belt, it re-crosses it again south-eastward from Kangaroo Point.

The southern, and so far unexplored, extension of the Ararat belt should pass in the direction of Yalla-y-Poora, where outcrops of Silurian rocks are shown to exist on the Geological Sketch-map. Careful prospecting is to be recommended in this locality.

Eastward from the Ararat and Stawell belt lies that of Navarre and Landsborough, on the southern extension of which, towards Buangor, there appears to be good scope for the prospector.

Next to the eastward lies the belt containing St. Arnaud, Stuart Mill, Red Bank, Moonambel, Percydale, Amphitheatre,

Waterloo, Raglan, and Beaufort, all within a strip of moderate width, having a direction approximately coincident with the strike of the Silurian rocks. Northward from St. Arnaud the country consists of wide plains, to prospect the deep alluvial deposits of which would be expensive and difficult, though perhaps future discoveries may warrant the attempt being made; but on either side of a line from St. Arnaud to Beaufort there is a considerable extent of country worthy of careful search, and many reefs once worked, but now abandoned, which would in all likelihood pay well were work resumed on them.

The range lying between Raglan and Waterloo, and terminating at Beaufort, offers special inducements to the quartz prospector, as from its denudation in past times a great quantity of alluvial gold must have been derived, and there ought to be unremoved reefs remaining, which contain gold in payable quantity. Gold has been found south from Beaufort to the verge of the Lilerie Plain, the deep ground of which is untried, and across that plain far to the south, on the apparent prolongation of the belt, are the Skipton diggings, thus indicating the probability of the maintenance of the auriferous character of the Silurian rocks beneath the plain. Of this, however, more will be said in connexion with the next two belts of gold-bearing country, one of which contains —north of the plains—Bealiba, Homebush, Avoca, Lamplough, and Lexton ; on the south, Carngham, Linton, and Happy Valley. The other comprises:—North—Wedderburn, Wehla, McIntyre, Berlin, Moliagul, Goldsborough, Dunolly, Timor, Maryborough, Amherst, and Talbot ; south—Haddon, Smythesdale, Scarsdale, and Rokewood. It may be remarked that though names of detached localities are given to indicate the course of the belts, there are really but few breaks in the continuity of the auriferous character of the last-mentioned from Wedderburn to Talbot, and from Haddon to Rokewood. Alluvial diggings have been worked all along from place to place in both sections of the belt, the gap between which is occupied by the outcropping granite of the Mount Beckworth Range, and the basaltic plains extending westward from Ballarat to the Hopkins Valley, through Lilerie, between Beaufort and Carngham. Underneath these plains must lie the extensions of the leads trending west from Ballarat, of those of Haddon, and doubtless many others at present unknown. These are evidently joined near Lilerie by the Waterloo leads, and several others near Beaufort. There is every probability that where these leads cross the three last-mentioned belts, beneath the Burrumbeet and Lilerie Plains, eastward of a line from Beaufort to Carngham, there may exist a deep alluvial gold-field equal to any yet found in Victoria, and that the northern and western lead system of Ballarat, though impoverished immediately west of that city, may be found to have received a wonderful accession of

wealth after crossing the courses of the three auriferous belts above described. Though the relations are somewhat obscure, I am inclined to class in the next belt to the eastward the gold-fields of Kingower, Jones' Creek, Carisbrook, Majorca, and Clunes north of the plains, and the Whim Holes and other workings to the south-westward of Ballarat. The deep leads on this belt between Clunes and Miners' Rest should prove payable.

Proceeding eastward, the next belt may be described as the most important in Victoria. From the geographical position of the various localities in relation to one another, and to the general strike of the Silurian rocks, I regard as constituting exposed portions of one great auriferous zone the gold-fields of Inglewood, Tarnagulla, and Kay's diggings, north of the plains of the Loddon Valley, and to the south the gold-fields of Smeaton, Kingston, Creswick, Ballarat, Buninyong, and the Durham ; the last-named southern localities are continuous with one another as regards auriferous character, there being no break from the Durham to Smeaton, a distance, north and south, of 25 miles, in the alluvial gold-workings, over a width averaging, from east to west, about 4 miles.

Southward from the Durham, the belt becomes poorer in gold, the deep ground having so far proved unremunerative, and the shallow diggings scattered and patchy. It is noticeable, however, that the bed of the Leigh River has been profitably worked for 20 miles down from the Durham, and that auriferous gravels have been traced from its banks under the basaltic plains south of Mount Mercer, where the further continuation of the Durham gutter is sure to exist. It is, therefore, quite likely that the belt of Silurian rocks extending southward from Ballarat may here be found to have regained its auriferous character, and that the deep gravels resting on it beneath the basalt may be as rich in gold as those to the north.

As regards the unexplored portion hidden by basalt, between Smeaton and Tarnagulla, the indications are most hopeful ; there is every reason to believe that the belt retains its auriferous character from the Madam Berry mine to Tarnagulla, a distance of 30 miles, and that all the alluvial gravels between the basalt on its course will prove profitable.

On a smaller scale, the flat alluvial country along the Bul Bul Creek, between Tarnagulla and Inglewood, is likely to prove auriferous in the vicinity of a line between the two places.

Separated from the Ballarat and Durham auriferous belt of country by a broad strip, in which no gold workings of importance have been discovered, the next to the eastward is the Elaine and Mount Doran belt, too isolated to admit of its true relations to others being determined ; it is, however, noticeable that the commencement of the Hepburn Home Paddock lead is approximately

where the prolongation of this belt might be expected to be, and it may be inferred that auriferous deposits are likely to be found where Silurian rocks constitute the "bottom" beneath the great basaltic areas of Warrenheip, Bungaree, and Dean, in the vicinity of a line from Mount Doran to the Hepburn Home Paddock.

Steiglitz, the Moorabool diggings, Mount Egerton, Gordon, the Korweinguboora reefs, and the workings westward of Daylesford and thence to near Yandoit, constitute another belt of auriferous country along which further discoveries are likely to be made, especially in deep alluvial ground southward of Egerton, along the Moorabool Valley, and between Gordon and Egerton, where the position of deep ground has lately been ascertained by means of boring with the diamond-drill.

Next to the eastward is a very important auriferous belt commencing at the north with Maldon, and extending thence southward along Sandy Creek, Jim Crow Creek, Daylesford, and thence to Blakeville. Further south on the same course payable gold has been found near the Ballanee estate and along the Werribee River to within a few miles of Bacchus Marsh. The deep alluvial ground in the Loddon Valley, near Newstead, may be expected to be payable below where it crosses this belt, and towards the southern extremity the deep ground of the Ballanee estate is also deserving of exploration.

Castlemaine, Chewton, and Fryerstown form portion of another auriferous zone, the northern continuation of which, beyond the granite of the Big Hill Range, is indicated by the gold-workings of Myers Creek.

To the south, Trentham, Newbery, Blue Mountain, Barry's Reef, and Blackwood all lie in the same strike, the southern extension being apparently the Lerderderg workings and Goodman's Creek, near Bacchus Marsh.

Raywood, Sebastian, the Whipstick, Eaglehawk, and Sandhurst, north of the granite of the Big Hill Range, and south thereof Taradale and Malmsbury, appear to constitute a distinct belt, broken in continuity by the granite; the northern extension of this belt may be found under the plains beyond Raywood, and the southern beneath the volcanic area around Kyneton.

In both the Castlemaine and Sandhurst belts there are great probabilities of future valuable discoveries in the shape of auriferous quartz reefs, both near the surface and at great depths.

This closes the list of the more important and well-marked belts of auriferous country where Lower Silurian strata form the bedrock.

Heathcote, about the line of contact of the Lower and Upper Silurian rocks, and the neighbouring gold-fields of Redcastle and Costerfield, with those of Whroo, Graytown, and Rushworth,

further eastward, all in Upper Silurian strata, appear to form several small separate belts, the relations of which have not been investigated.

Reedy Creek, Strath Creek, Diamond Creek, Warrandyte, and other workings are all situated on what—judging from the observed bearings of strike in various localities—is a curved belt of rocks, the southernmost known auriferous locality on which is near Templestowe.

The Ghin Ghin diggings, Yea, Higinbotham, and—to the south of the granite and trap of the Watts Valley—Warburton and Hoddle's Creek appear to indicate another curved belt, though the relations between the rocks of the various localities are uncertain.

Proceeding eastward, the next belt is a very well-marked one, the various gold-workings being situated along a zone of Upper Silurian rocks, having a well-defined north-westerly strike. The principal diggings are Merton, Gobur, Growlers, Spring Creek, Alexandra, and the Acheron diggings, in the Goulburn drainage-area, and north of the granite of the Main Divide, while to the south are the workings of Cumberland Creek, the Upper Yarra, Hawthorn, Pheasant and Russell's Creeks, and Tanjil. Several scattered gold-workings have been opened on either side of the main line of this belt, such as Crossover, in Gippsland, the workings up the eastern branch of the Tanjil, and on the upper portion of the Tyers, indicating the existence of other parallel strips of auriferous country. There is a very good field for future mining enterprise upon the course of the Merton to Tanjil belt, there being a considerable extent of volcanic country on the Gippsland side, which is likely to be underlaid by auriferous gravels, and abundant scope for the prospector in quartz reefing. Most of the known auriferous reefs on this belt are associated with diorite dykes, which have an easterly and westerly direction *across* the strike of the Silurian rocks.

The next well-defined auriferous belt is the most important in the Upper Silurian country, and is nearly 100 miles in length. On it are situated, in the Goulburn drainage-area, the Strathbogie diggings, Maindample, Jamieson, Enoch's Point, Gaffney's and Raspberry Creeks, Wood's Point, and Matlock; on the fall towards Gippsland, BB Creek, Jericho, Aberfeldy, and Walhalla, the latter place being celebrated for the Long Tunnel mine, the premier quartz mine in Victoria. In nearly all the quartz workings along this belt the reefs accompany, or are intimately associated with, diorite dykes having a direction *coincident* with the strike of the Silurian rocks.

There is a fair field for the prospector in the many untested portions of country intervening between the proved gold-workings on this zone.

The relation to other gold-fields of Foster and Turton's Creek, in South Gippsland, cannot well be indicated on account of the great extent of country occupied by Mesozoic rocks which intervenes. It is by no means improbable that the lowest beds of the Mesozoic strata, immediately resting on the Silurian rocks about a line between Foster and Turton's Creek, may consist of auriferous conglomerates.

Turton's Creek offers a tempting inducement to search for the source from which the exceedingly rich alluvial gold found there was derived.

A small belt in which the quartz reefs are not associated with diorite dykes is formed by the Royal Standard Reef on the fall towards the Goulburn, and the Donnelly's Creek Reefs in Gippsland; the extensions of this belt southward from Donnelly's Creek and northward from the Royal Standard have not been discovered.

In the north-eastern part of the colony we have the great auriferous belt which includes—on the fall towards the Murray—the gold-fields of Rutherglen, Chiltern, Barnawartha, Eldorado, Yackandandah, Beechworth, Stanley, Myrtleford, Bright, the Buckland, Wandiligong, and the various workings along the Ovens Valley to Harrietville. On the Gippsland side—the Dargo and Cobungra, Grant, Crooked River, the Wentworth, Swamp Creek on the Mitchell, Boggy Creek, near Bairnsdale, and other gold-workings. The Mitta Mitta and Dark River workings, those of Omeo, Swift's Creek, the Tambo and Nicholson Rivers, Zulu and Gibbo Creeks, and, in the far east, Bendoc, all demonstrate the existence of further zones of gold-bearing country, the northerly and southerly continuations and also intermediate portions of which it would be desirable to test.

The above general description is only intended to roughly indicate the main zones, each of which would, if examined, be found to comprise a number of minor distinct belts, and each of these again a number of separate lines of auriferous quartz reef or evidence of the existence of the latter in the form of auriferous alluvial deposits.

Along the lines of all the belts or of their extensions are unproved tracts of exposed Silurian country in which surface prospecting could be easily carried on, or areas covered with sedimentary deposits and lava-flows, under which there would be a fair chance of discovering fresh sources of gold supply. Attention may be drawn to the advisability of more careful exploration than has yet been made in search of lines of auriferous quartz reef. The extent of proved auriferous alluvial ground is so very large, and it has been in many places so exceedingly rich, that the number of quartz reefs actually worked, and the extent to which they have been developed, seem ridiculously small in

comparison. It is not an exaggeration to say that there are miles in length of auriferous alluviums for every hundred yards of worked quartz reef.

Making full allowance for the fact that the auriferous alluvial deposits are the results of the enormous denudation to which the Silurian rocks have been subjected, and the disintegration with them of an incalculable amount of auriferous quartz; and further, keeping in view that the portions of the reefs so denuded were probably richer than what remain; nevertheless the known tendency of gold to remain stationary or simply to drop deeper, and the fact of so many rich gullies and leads having been worked up to ranges where the quartz reefs still remain practically untested, all tend to justify the conviction that there are undeveloped stores of wealth in our untried quartz reefs, and in the unexplored continuations of those that have been worked, far exceeding in amount the yields hitherto obtained.

Admitting the principle that where there is an auriferous alluvial deposit there is likely to be an auriferous matrix not far distant, there is an unlimited field for exploration lying open for mining enterprise, a field in which—though, as in other undertakings, failures will be encountered—counterbalancing successes will certainly reward patient and judiciously conducted search.

Other Metals.

Of metals other than gold there are few that do not occur in some form or other in Victoria, but although among these, silver, copper, antimony, tin, lead, and iron have been found in various localities in sufficient quantity to encourage efforts towards working them, no great successes have been achieved.

Antimony at Costerfield and Ringwood, copper at Walhalla and Bethanga, stream tin in the Beechworth and Upper Murray districts, and argentiferous lead ore at Buchan, have been worked in some instances successfully, in others have proved failures.

No doubt in time our resources will become better developed; but the fact cannot be gainsaid that in all metals except gold Victoria is far poorer than the sister colonies; on the other hand, her pre-eminence in gold is likely to counterbalance the dearth of other metals, and to assure to her for centuries to come a leading position as a gold-mining country.

CHAPTER XV.

Remarks on the Coals and Lignites of Victoria.

In considering the question as to whether coal sufficient for home requirements will ever be produced from Victorian mines, it may be stated at the outset that we have not any exposed representatives of the true Carboniferous rocks of Great Britain and New South Wales; it is possible, but does not appear to be very probable, that such rocks may exist concealed beneath the Mesozoic rocks, or beneath the Tertiary beds of the north-western part of the colony; their non-existence in any part of the main mountain system of the country is an ascertained fact. The only rocks in which exploration for coal can be carried on with any hope of success are the Mesozoic rocks of the areas already described, namely, the Wannon area, the Cape Otway area, or that lying between the road from Geelong to Warrnambool on the north, and the sea-coast on the south; and the Western Port and South Gippsland Mesozoic area, or that lying between the Western Port, Lang Lang, and La Trobe valleys on the north, and the sea-coast on the south. It has already been shown that the Wannon and Cape Otway beds may be continuous with one another beneath the intervening Tertiary formations, and that the latter may extend for some distance under the great volcanic plains northward from Colac.

As far as geological age is concerned, there is actually no reason whatever why our Mesozoic rocks should not contain large and payable seams of coal; rocks of the same or even of more recent periods do contain such seams in other countries.

Sir R. Daintree, in his work on the Geology of Queensland, describes the Carbonaceous Mesozoic rocks of that country as geologically identical with those of Victoria, and as containing good workable coal seams on the east of the Dividing Range, where apparently of lacustrine origin, though the marine beds on the west of the divide appear to contain no coal.

The only question with us is, whether at any periods during the deposit of our Mesozoic rocks the conditions for the formation of large seams over wide areas were present; that they were to a certain extent is proved by the seams which have been found, and recent developments have tended to strengthen the belief that we are not so poor in sources of coal supply as many are inclined to imagine. Our main hopes are, however, centred in the Western Port and South Gippsland Mesozoic area, where a tract nearly

equal in size to Northumberland has been proved to contain coal seams at various localities round the edges, and also in the central portions.

As regards the Cape Otway and Wannon districts the indications are not so favorable, though geologically their Mesozoic rocks are identical with those of Gippsland and Western Port.

At Coleraine are small seams of an inferior description of coal, the largest seam being about 20 inches in thickness. A small seam of good coal exists near Colac, but it is not large enough to be profitably worked, and of several diamond-drill bores put down in the district to nearly 1,000 feet, not one revealed the existence of another seam.

The deep bore at Portarlington, over 1,500 feet, passed through no coal, though carbonaceous laminæ occurred in all the cores of rock brought up.

The same result attended the bore at Winchelsea, which was carried to a depth of more than 2,100 feet.

Some small seams of good coal occur near Apollo Bay, but have not been sufficiently explored to admit of a definite opinion being formed as to their probable value. Altogether, the prospects of a workable coal-field west of Port Phillip are very slender.

In the eastern Mesozoic area the evidences are of a far more encouraging description, and, as before stated, there is a large tract beneath which extensive coal mines are likely at no distant date to be developed.

Concerning a number of the known and earlier discovered seams of coal and their modes of occurrence, information will be found in the Geological Progress Reports; but I propose here to recapitulate the main features of that information, and can do no better than repeat the description given in Progress Report No. VII., with additional observations as to discoveries and developments effected since its publication.

Coal has been proved to exist in various localities throughout the area under notice. Along its southern or coast boundary, along the northern or inland margin, and at several places in central portions.

Commencing at the coast-line, and proceeding south-easterly from Griffith's Point, the following are the principal known coal seams :—

The Sandy Waterholes seams are exposed in cliff section on the coast, about 5 miles from Griffith's Point, and are five in number, all within a total thickness of 50 feet. The two middle ones, 2 feet apart, are each from 18 inches to 24 inches thick, the others being smaller; they dip inland, and it is stated that, in a shaft now filled in, situated 100 yards back from the cliff, a seam was cut which showed a thickness of 24 inches of coal.

Deteriorated as they are by exposure on the face of the cliff, it is difficult to pronounce with certainty on the quality of these seams, but it appears likely to be very good if they are followed in; and as their extension inland could be tested for a few hundred pounds, and they are within so short a distance of the shipping place, they are certainly worthy of exploration.

The Kilcunda seam has been worked in from the face of the cliff by means of an adit, and further inland from a shaft 100 feet deep. Several "faults," one of which is a down-throw of 40 feet, dislocate this seam; but it has been followed from the shaft along its strike (about W. by N.) for more than 1,000 feet without a break.

The quality of the coal is excellent; its thickness varies from 20 inches to 27 inches, or an average of barely 24 inches. The "holing" is hard, and necessitates some waste in cutting; but, nevertheless, men of long and varied experience maintain that, with proper management, this seam can be worked at a profit. Its inclination is inland, somewhat E. of N. at 10°. Some 5,000 tons were raised and sent to Melbourne by the first company which worked the mine, but proper arrangements for mining and carriage were not perfected, and the undertaking collapsed. A second company, formed under what appeared to be better auspices, constructed a railway from the mine to the shipping place, and sent a considerable quantity of coal to market, but gave up, owing to the discouraging results of several diamond-drill bores put down, at very ill-selected sites, to ascertain the extent and trend of the seam prior to sinking a new main shaft, which was found to be essential to the further development of the mine. The ground is, therefore, at present lying unworked.

Of several diamond-drill bores put down in the neighbourhood, one to the north of the mine proved a 20 to 24-inch seam at 165 feet, besides a number of small ones down to 873 feet. From another bore, on Bridge Creek, 3 miles east of the mine, a core showing 32 inches of coal was obtained at 490 feet, besides other smaller ones above and below that depth.

Seven miles east from Kilcunda, a bore put down near the Powlett River passed through two seams, one at 349 feet and another at 687 feet, each about 30 inches in thickness, and consisting of good coal.

The diamond-drill bores near Kilcunda, at the Bridge Creek, and at the Powlett River, have satisfactorily established as a fact that the coal seams are not mere patches.

The value of the information obtained by means of the last-mentioned bore, as to the existence of two workable seams of good coal, at easily accessible depths, and in nearly horizontal strata, may in itself be regarded as an equivalent for all the expenditure on diamond-drills since their introduction into the colony. The

statement made in a former report—that we had, at the time that report was written, no guarantee as to the continuance of any known coal seam beneath a single square mile—may now be withdrawn. We have evidence of their continuance beneath many square miles, and of the probable existence of many millions of tons within a short distance of the surface, and within convenient distance of a shipping place.

From the mouth of the Powlett River, 3 miles east from Kilcunda, for a further distance of some 4 miles, nothing is to be seen of the rocks along the coast; but thence for 12 miles, by Coal Creek and Cape Patterson to within a short distance of Anderson's Inlet, they are visible the whole way, and afford excellent opportunities for observation.

At about the first exposure of rocks on the coast, travelling from the Powlett towards Coal Creek, there are three small seams, and further on a seam of about 10 inches of good coal with several feet of black "clod" beneath it; these are only visible at times when the tide is low and the sand temporarily removed. About this locality it is stated that a seam of 20 inches was proved inland among the hummocks, but has since been obscured by blown sand.

A mile westerly from Coal Creek is a coal seam of from 20 to 24 inches between two smaller ones of 4 inches each, all dipping N.W. at 40°. This dip is exceptionally high and abnormal in direction, the rocks on both sides, for some distance, dipping from S.S.W. to S.S.E. at from 4° to 14°. In this locality, however, much disturbance, variation of dip, and false bedding are visible in the strata.

Two or three other small seams occur between here and Coal Creek, west of the mouth of which are the two main seams, the "Rock" and the "Queen" veins. Where exposed on the coast, these seams dip W.S.W. at about 30°, but in a shaft (known as Bury's or Davis' shaft) sunk through them a few chains inland, the inclination is only 15°.

The section in the shaft is as follows:—Measures (sandstones, shales, &c.), 57 feet. Upper coal seam—total thickness, roof to floor, 30 to 36 inches, with irregular partings, reducing the available thickness of coal to about 24 inches.

Measures with a small 4-inch seam, 11 feet. Lower coal seam—total thickness 42 inches, divided by impure bands into three portions of 2½ to 3, 2½ to 3½, and 22 to 24 inches respectively. These measurements represent the general average, as no two sets of measurements taken, whether in different parts of the shaft, or on the coast outcrops, tally exactly, owing to variations in the thickness of the coal and partings.

On the whole, I would estimate an available thickness of 24 inches of coal to be the average for each seam as now visible.

Eastward of Coal Creek, between it and Cape Patterson, the basset-edges of some thirteen distinct seams are visible in the rocks; all have a S. to S.S.W. dip at about 12°; the largest of these only is of workable size, and is from 20 to 24 inches thick; it was worked a short distance inland by the late Victoria Coal Company, about twenty years ago, and yielded 1,900 tons of coal before being abandoned on account of the difficulties of shipment.

At Cape Patterson, Mr. N. Levi has sunk a shaft, and cut the coal seam worked many years ago by the Victoria Coal Company—on the inland side of a disturbing fault—and though the available thickness of workable coal, so far as exposed, is rather small, the quality is most excellent. The total thickness of the seam is about 2ft. 6in., including impurities, but these may be expected to disappear as the seam is traced inland, in which direction it has been proved to extend, and to increase in size, by a number of diamond-drill bores that have been put down. The last bore passed through a seam of 43 inches, of which 2 feet was good, and the rest somewhat impure.

About Coal Creek and Cape Patterson there are several large and small basalt dykes, which intersect the rocks, and will assuredly be found to locally affect and probably "fault" the coal seams.

The prevailing north-easterly dip of the ascending series of rocks, visible from Cape Patterson towards Anderson's Inlet, the more regular and even character of the layers, and the absence of dykes in that direction, are favorable indications that the large Cape Patterson seams passing beneath them will be found to underlie a great area, and to continue tolerably persistent and unbroken northward and north-eastward from Cape Patterson.

As pointed out long ago by Mr. A. R. C. Selwyn, the "Rock" and "Queen" veins at Coal Creek are likely, from their south-westerly or seaward direction of dip in that locality, to outcrop inland, assuming such direction of dip to be maintained; but, from observations of the dips of the rocks generally along the coast, it appears that the undulations of the beds are such that not only do they incline north-eastward from Cape Patterson, but also change their dip northerly from Coal Creek, and incline inland, as though to pass under the lower part of the Powlett Valley.

Indeed, the idea that the Sandy Waterholes seams are the western outcrops of the Cape Patterson seams, and that they underlie the Kilcunda seam, is not so far-fetched as may at first sight appear; but, nevertheless, the variable character and dip of the rock-layers, and the absence of any markedly distinctive rock-bands, forbid the adoption of any special theory.

In the ascending series of beds visible from Cape Patterson to Anderson's Inlet, there occur a few small coal seams, but, save one of from 10 to 20 inches, none that appear likely to become of importance.

At Foster, in the bed of Stockyard Creek, and close to the boundary of the Silurian rocks, is a coal seam which possibly may be worthy of more attention than has yet been bestowed upon it. The coal itself is of fair quality, and as far as followed it dips north-westerly in a succession of descending shelves, the thickness of which increases downwards from 10 to 20 inches. Further insight into the character of this seam could be obtained at very small expenditure.

Between Foster and Port Albert the measures were proved in bores to a considerable depth, and, it is stated, small seams of coal were discovered more than twenty years ago.

Along the northern portion of the carbonaceous area there are on the Bass River and in the adjacent ranges several outcrops of coal seams up to 20 inches in thickness, some of which have not yet received much attention. In the head of the Bear Creek, a main branch of the Moe, is a seam (described in Progress Report No. III. as O'Mahoney's seam) of excellent coal, though only 9 to 11 inches thick; this seam dips south-easterly at 32° (an abnormally high angle, not likely to be maintained far), and, as it shows signs of increase on its dip, is worthy of further trial.

In the extreme north of the carbonaceous area on Rintoul's Creek, 8 miles north of Traralgon, is a seam of bituminous shale 10 inches thick, which yields a good illuminating oil, and burns well, but leaves a strong residue of undiminished bulk. This exposure is only the edge of the layer, as the Silurian rocks appear a short distance up the creek; it dips south-easterly, and is very likely to increase in thickness in that direction.

The Hazelwood seam outcrops on a branch of Billy's Creek, 8 miles S.S.E. from Morwell.

In the width of a heading driven along it for a distance of 18 feet, the coal increases from 20 to 28 inches, with indications of still further increase on its dip, which is to the S.E. at 27° (a high rate of inclination, not likely to continue far).* The coal, as far as proved, is soft, but burns well, caking and blistering strongly, and appears likely to yield a very good coke.

The Moe coal seam is one of the most promising in Victoria; there are two exposures, about 2½ miles apart, and, though not a matter of absolute certainty, these appear to be different outcrops of the same seam. The western outcrop is at the head of Mosquito Creek, 4 miles S.W. from Moe, on the fall towards the Moe Swamp. Near the surface exposure only about 16 inches out of a total thickness of 24 to 28 inches is good coal, but as followed beneath its proper roof, it improves, and shows about 24 inches of good coal; this seam rests on a clay

* This seam has since been cut in a drive from a shaft sunk about 20 yards from the tunnel, and shows an average thickness of about 3 feet.

floor. The eastern exposure, in Messrs. Stephenson's selections, is in the head of a gully running into the northern tributary of the Narracan; here the coal has been followed from its outcrop beneath its proper roof, and shows in the tunnel-face a thickness of from 30 to 32 inches of first-class coal, with only one thin insignificant clay parting; it rests on a clay shale floor, and is covered by a thick sandstone roof. The dip is southerly at about 10°, a direction and rate of inclination which carries the seam under the Narracan Valley, where other exposures of coal, as now being tested, are visible. One of these outcrops is in the bed of the creek in the Narracan Valley Company's ground, and, as far as traced, shows a thickness of about 20 inches of good coal, with indications of increase as followed in. This seam I consider to be the Moe seam, and it rises to the southward on the south side of the valley showing a synclinal "roll" in the measures. The seam, 30 inches thick, which was struck at 117 feet in a diamond-drill bore in the Narracan Valley, appears to underlie the Moe seam.

On the Moe seam, in Mr. Stephenson's selection, very satisfactory exploration has been effected by the Moe Coal Mining Company. From the outcrop, in a southerly direction for a distance of half-a-mile, bores were put down at short intervals, and, in each case, proved the continuance of the seam, and the maintenance of its workable thickness and quality. A shaft was sunk near the southernmost bore, and struck the seam, which averaged 27 inches of good coal. An adit was then driven, and met the coal seam on its southerly dip, the shaft being utilized for ventilation. A level has since been extended for several hundred feet along the coal, which varies from 20 inches to 30 inches in thickness, and is, so far, only slightly displaced by a few trifling faults, which will facilitate, rather than render difficult, the working of the seam. There will be at least half-a-mile up the incline of the seam, and probably 2 miles along its strike, to be worked from the adit without expenditure for winding or pumping machinery. Taking an average of 2 feet of coal, this gives over 2,000,000 tons available from the adit, and deliverable within a few hundred yards at the Narracan Valley Railway, whenever that line be constructed, and there is no reason to doubt that, small as is the thickness of the seam, compared with those of other coal-fields, the ease with which it can be mined and taken direct to the railway trucks will enable the company, when in full work, to realize a fair profit over and above working expenses, royalty, and interest on outlay.

The Narracan Valley Company will be able to mine by means of shafts the southern extension of the Moe seam; and they have also several outcrops in their ground of other coal seams of good quality likely to attain workable dimensions when traced in from their exposures.

In the central portion of the area, on or adjacent to a line from Moe to Cape Patterson, are several coal outcrops, the most important of which is the Strzlecki seam, about 14 miles north from Anderson's Inlet.

There are two outcrops less than 2 miles apart, but whether of the same or of different seams is uncertain. The northern exposure is on a western tributary of the Tarwin, near the divide between that river and the Powlett.

In a cutting there is exposed, in a height of 7 feet, an aggregate thickness of 3 feet of good coal, in three separate seams of 12 inches, 8 inches, and 24 inches respectively, the lower 18 inches of the latter, or undermost seam, being very good indeed.

The southern outcrop is in a gully trending to the Powlett, and here a short tunnel has revealed the existence of a seam (dislocated to the extent of 3 feet in one place by a "fault") containing at the face of the tunnel an unbroken thickness of from 30 to 32 inches of excellent coking coal.

Whether the same or different seams, there is good reason to believe that the coal exposed in these two outcrops underlies a great area, and the discoveries made by means of so small an amount of labour amply justify further research.

In the heads of the Tarwin, between the Strzlecki seam and Moe, are several other outcrops, some of which show as much as 16 inches of good coal; but none of these, so far as I am aware, have been in any way tested as to their extent.

The most important seam yet found in Victoria is the Mirboo seam, the outcrop of which is in Berry's Creek, about 2 miles from the Mirboo Railway Station, on the property of Mr. William Scarlett. A shaft sunk a short distance from the outcrop passed through the seam at between 40 and 50 feet, and revealed a thickness averaging 56 inches of solid coal. The seam dips at the high angle of 32° in the shaft, but as the rocks exposed at surface up the creek, in the direction of the dip, show a much flatter inclination, it is certain that the seam will conform thereto.

Considering its size, quality, and proximity to the railway line, there appears no room for doubt as to the remuneratively workable character of this coal seam if properly wrought.

The Boolara seam has recently been found in the bank of a branch of the Morwell, about a mile and a half from the Boolara Railway Station, and close to the Mirboo line of railway. This seam is 3 feet thick, and though the upper portion is somewhat impure near the outcrop it is of workable size. It is nearly horizontal, and can be easily worked by means of an adit. It is quite possible that this seam may be identical with the Mirboo seam, though the distance between the two outcrops, and the paucity of any data as to the dips and undulations of the rocks in the intervening tract, forbids more than the mere conjecture.

The outcrops of the above-described coal seams occur distributed throughout an area which is, as before stated, nearly equal to that of Northumberland, and is wholly occupied by rocks, whose geological position, though more recent than that of the true carboniferous rocks of England and New South Wales, is well within the range of coal-bearing rocks generally. As compared with those of the great coal-fields of the world, the coal seams are small, with the exception of the Mirboo seam, the thickness of which is regarded as about the most convenient known for economical working.

The measures generally are much faulted, and are subject to many variations of direction and rate of dip. Nevertheless the explorations already made show that the known seams are not mere patches, but extend over areas amounting in some cases to several square miles, with every indication of still wider extension. Some of these coal seams are of a thickness which, in other coal-producing countries, even in Great Britain, is deemed a workable size, provided the quality be good and the working conditions favorable. The thickness here assumed as the workable minimum under most favorable circumstances is 16 inches of marketable coal in one seam ; a standard far below the available thickness of coal contained in most of our seams.

Of our known coal seams, the quality, almost without exception, has been proved by analysis and experiment to be excellent; it is more splintery and suffers more loss in carriage than the New South Wales coal; but is, as a rule, superior to the latter for steam, forge, and household purposes.

There are evidences to show the likelihood that our known seams, even if they be but patches, are nevertheless patches of extent considerable enough to admit of their being profitably wrought ; and, in addition, there is no reason for supposing that the known outcrops, due as they are to removal, by denudation, of overlying strata, have all been laid bare at the best part of the seams they belong to. Lastly, there are, in the Victorian carbonaceous series, layers which do not appear at all, or whose extreme edges only are to be seen at the surface.

Among these, there exists the possibility, as pointed out long ago by Mr. A. R. C. Selwyn, of finding coal seams larger, and more valuable than any of those known.

On the Kilcunda seam, which only averages barely 24 inches, and where there is waste and difficulty in "holing," owing to the hardness of the floor, good miners could, when the mine was being worked, make fair wages at 7s. per ton for screened coal, finding their own powder, fuse, and candles, doing their own filling and timbering, and making their own roads from the main heading.

The coal of the Moe seam having a greater thickness, and a better "holing," can be mined at a cheaper rate, while that of the Mirboo seam, with its specially convenient thickness, should be excavated for still less.

The general conclusion that I have arrived at is that, though Victoria may never compete with New South Wales as regards export trade, she nevertheless possesses within her own territory resources of coal supply sufficient for the greater proportion of her own wants. These resources will be more and more developed with the extension of railways into South Gippsland.

The main cause for doubt as to the coal from the small-sized Victorian seams being mined at a profit consists in the fact, that all coal produced in Victoria must be conveyed a greater or less distance by railway, and it is possible that the cheaply-mined coal from the large seams of New South Wales, conveyed by water carriage from the mines to Melbourne, can be placed on the market at a price which would not pay the Victorian coal miner. Against this may be set the higher value of the Victorian coal for steam and household purposes, and the power that could be exercised by the State—without resorting to extreme protective measures—of fostering the industry by conveying the product at a nominal rate from the mines to Melbourne, along such railway lines as now exist or may hereafter be constructed. This would probably be found to work better than either imposing a duty on imported coal or giving a direct bonus for that produced in Victoria.

LIGNITES.

Some of our lignite deposits may eventually prove of value. The Lal Lal lignite does not seem to have found favour as a fuel, but is now being utilized in the manufacture of an excellent deodorant. The McKirley's Creek lignite in Gippsland is said to yield per ton 6,000 to 8,000 feet of a gas which gives a light equal in power to that of coal gas. There is likely to be found an extensive deposit of this lignite beneath the volcanic country of Neerim and Buln Buln.

Very extensive lignite deposits occur along the La Trobe, in the Tarwin Valley, and along the foot of the ranges east of the Tarra River in South Gippsland. These may at some future date prove valuable, either as fuel or sources of gas supply.

At Toongabbie is a bed of lignite, together with a layer resembling a bituminous clay, which latter, on analysis, yields a very high percentage of illuminating oil. It is, in fact, a sort of kerosene shale, though of far more recent geological age than that of New South Wales, being Upper Tertiary, whereas the latter is Upper Palæozoic in geological position.

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